

Model Application: Temperature Decision Support Tools (DSTs)

Eric Danner (NMFS-SWFSC)

December 6, 2017

Overview

Description of the Decisions Support Tools (DSTs)

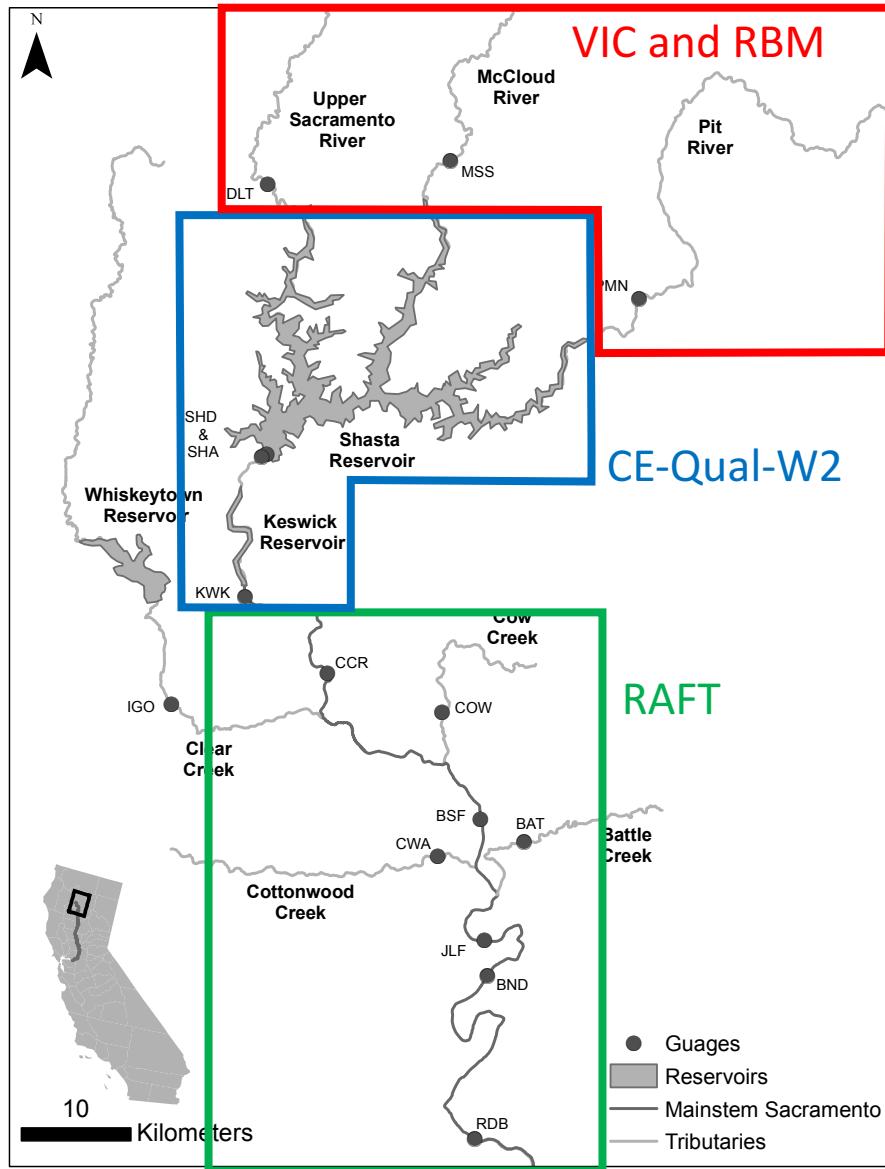
- Linked physical models
- CVTEMP website

Linking physical models to biological/ecological responses

- NMFS thermal tolerance model

Issues from previous reviews

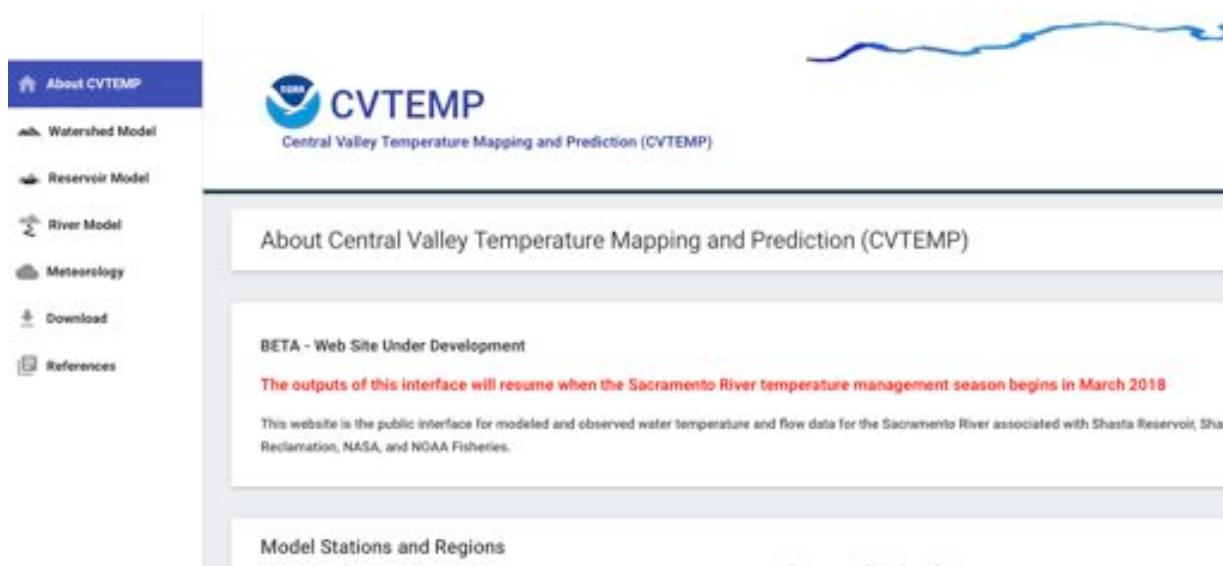
Linked Physical Models



Currently using data from the California Nevada River Forecast Center. Future versions will incorporate VIC and RMB.

Currently using an ARIMA model for the Keswick reservoir. Future version will extend CE-Qual-W2.

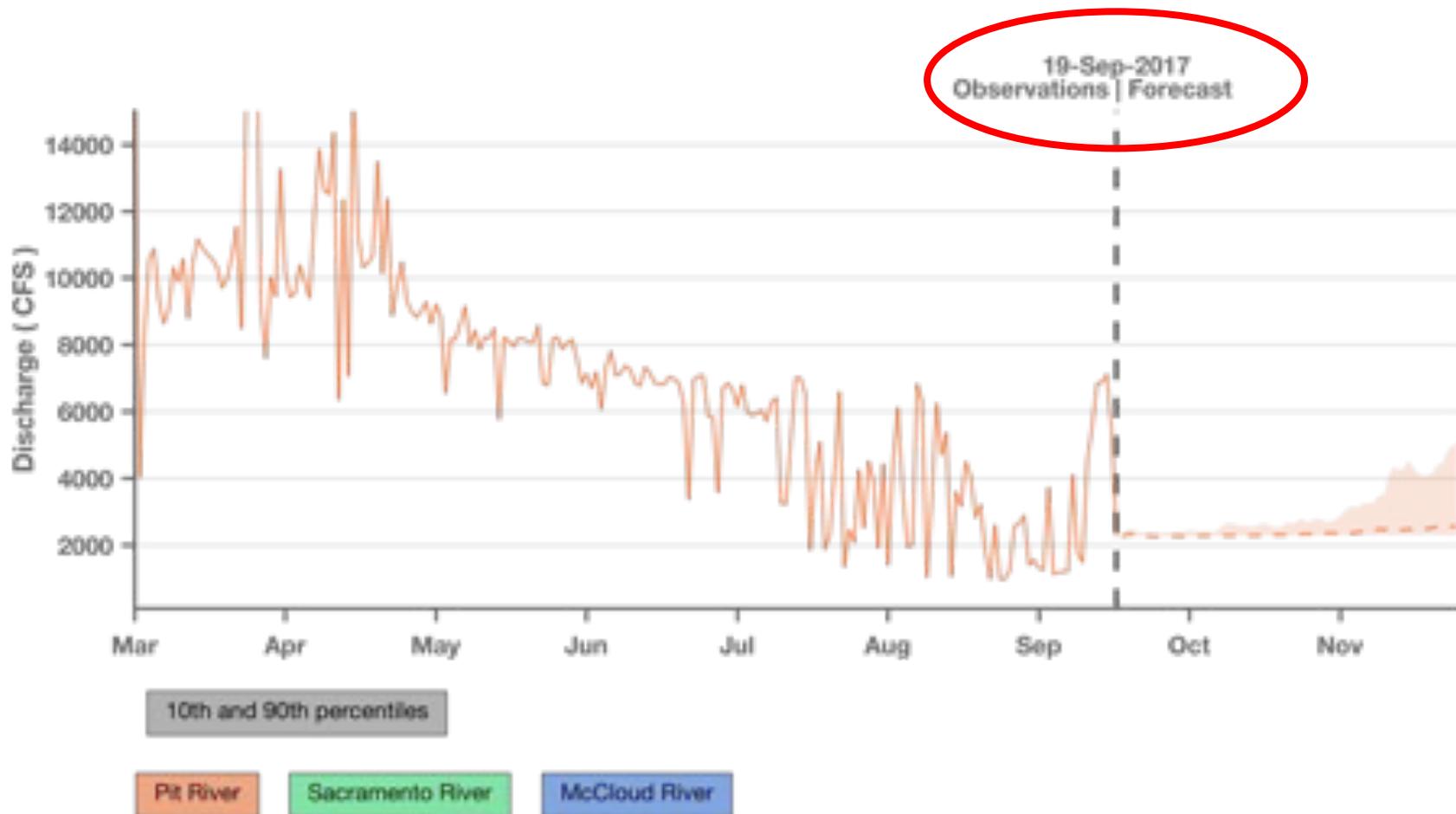
Central Valley Temperature Mapping and Prediction (CVTEMP)



The screenshot shows the homepage of the CVTEMP website. On the left is a sidebar with a blue header containing a house icon and the text "About CVTEMP". Below this are links to "Watershed Model", "Reservoir Model", "River Model", "Meteorology", "Download", and "References", each with a small icon next to it. The main content area features the NOAA logo and the text "CVTEMP" in large blue letters, followed by "Central Valley Temperature Mapping and Prediction (CVTEMP)". A decorative wavy blue line graphic is positioned above the main content. Below the title, a section titled "About Central Valley Temperature Mapping and Prediction (CVTEMP)" is shown. Underneath it, a red banner displays the text "BETA - Web Site Under Development" and "The outputs of this interface will resume when the Sacramento River temperature management season begins in March 2018". At the bottom of the page, there is a section titled "Model Stations and Regions".

<http://oceanview.pfeg.noaa.gov/CVTEMP/>

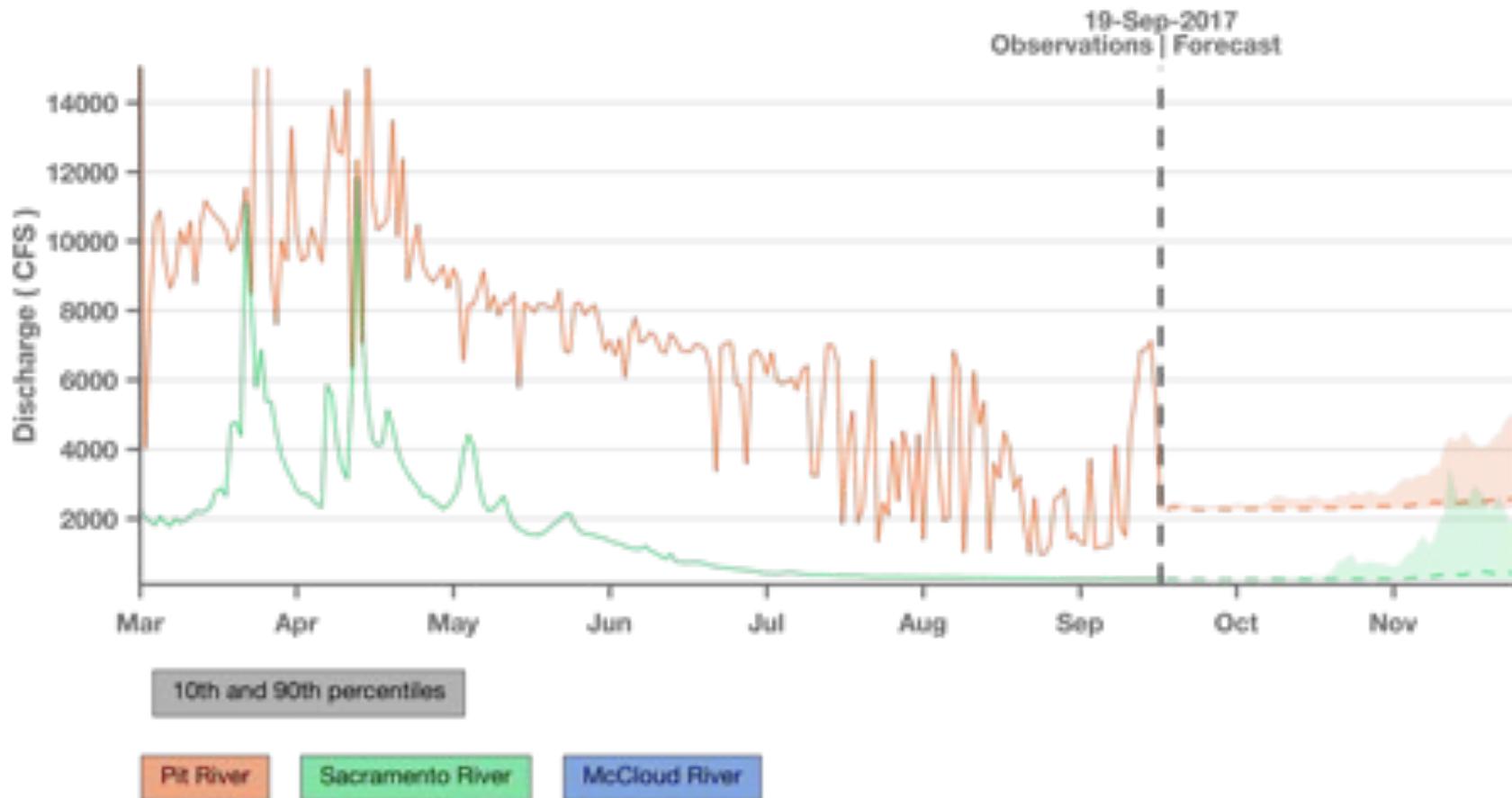
Reservoir inputs: flow



Note: Forecast from California Nevada River Forecast Center

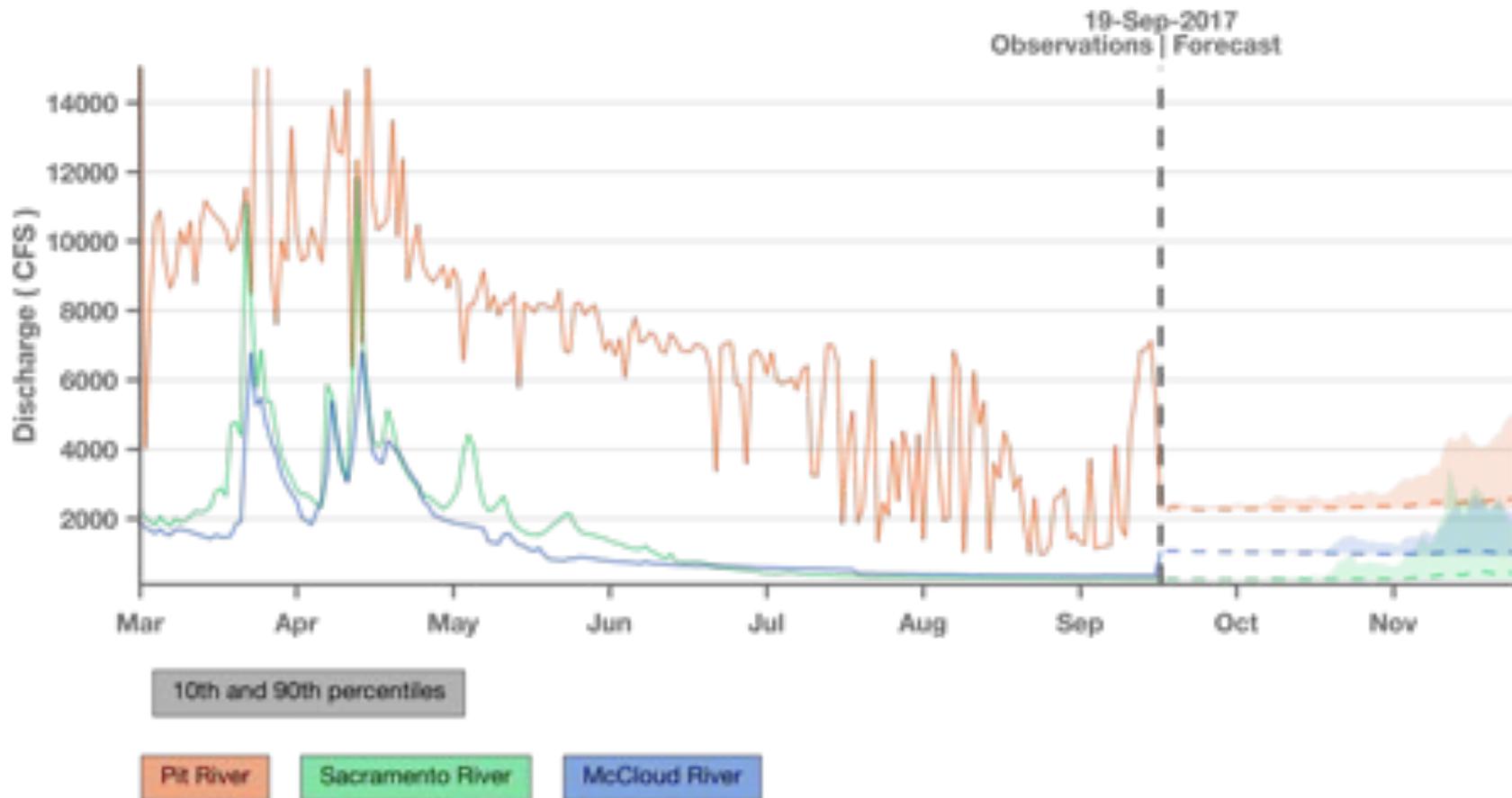
Observed and forecasted discharge inputs into Shasta Reservoir

Reservoir inputs: flow



Observed and forecasted discharge inputs into Shasta Reservoir

Reservoir inputs: flow



Note: Forecast from California Nevada River Forecast Center

Observed and forecasted discharge inputs into Shasta Reservoir

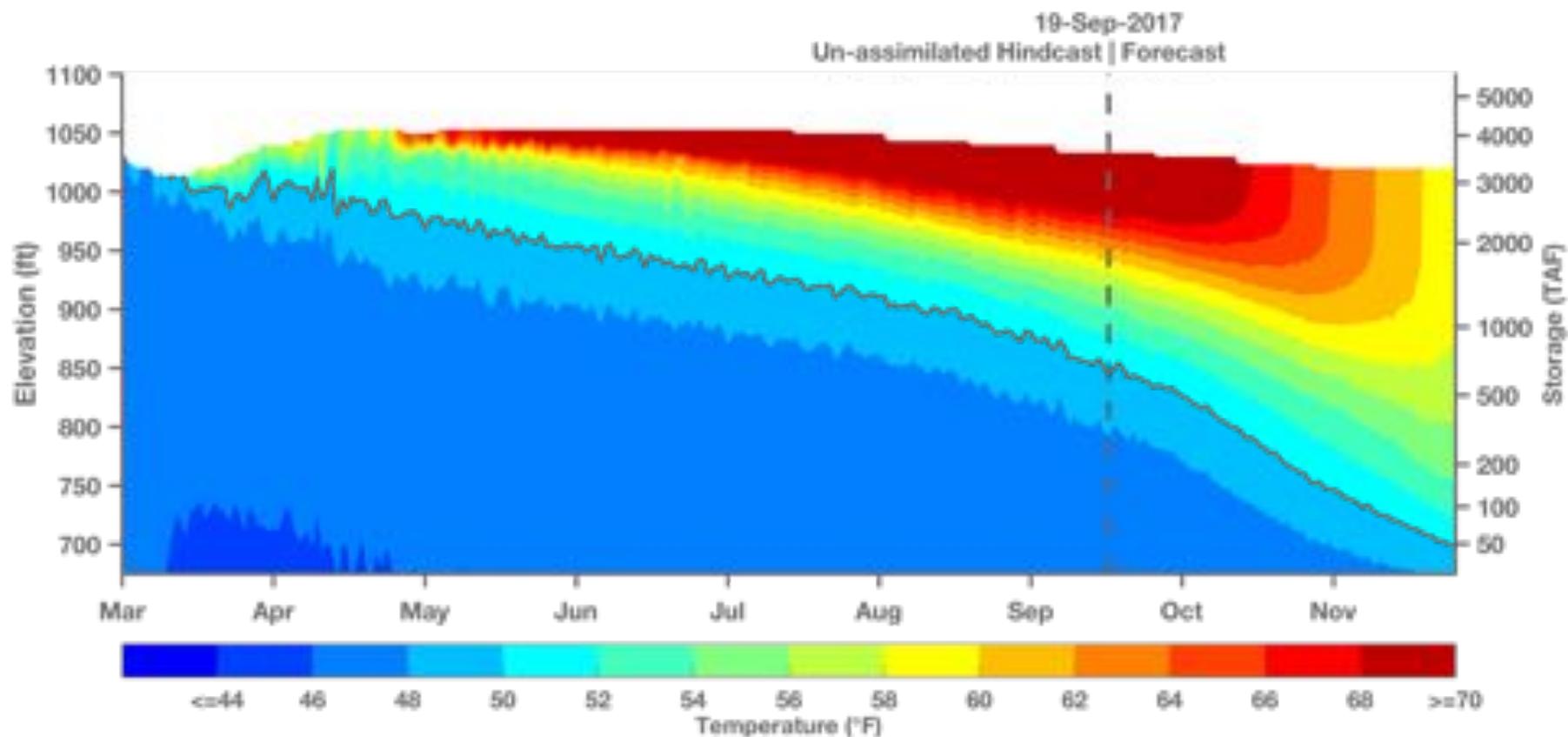
Reservoir inputs: temperature



Note: Forecast based on range experienced from 2000:2015

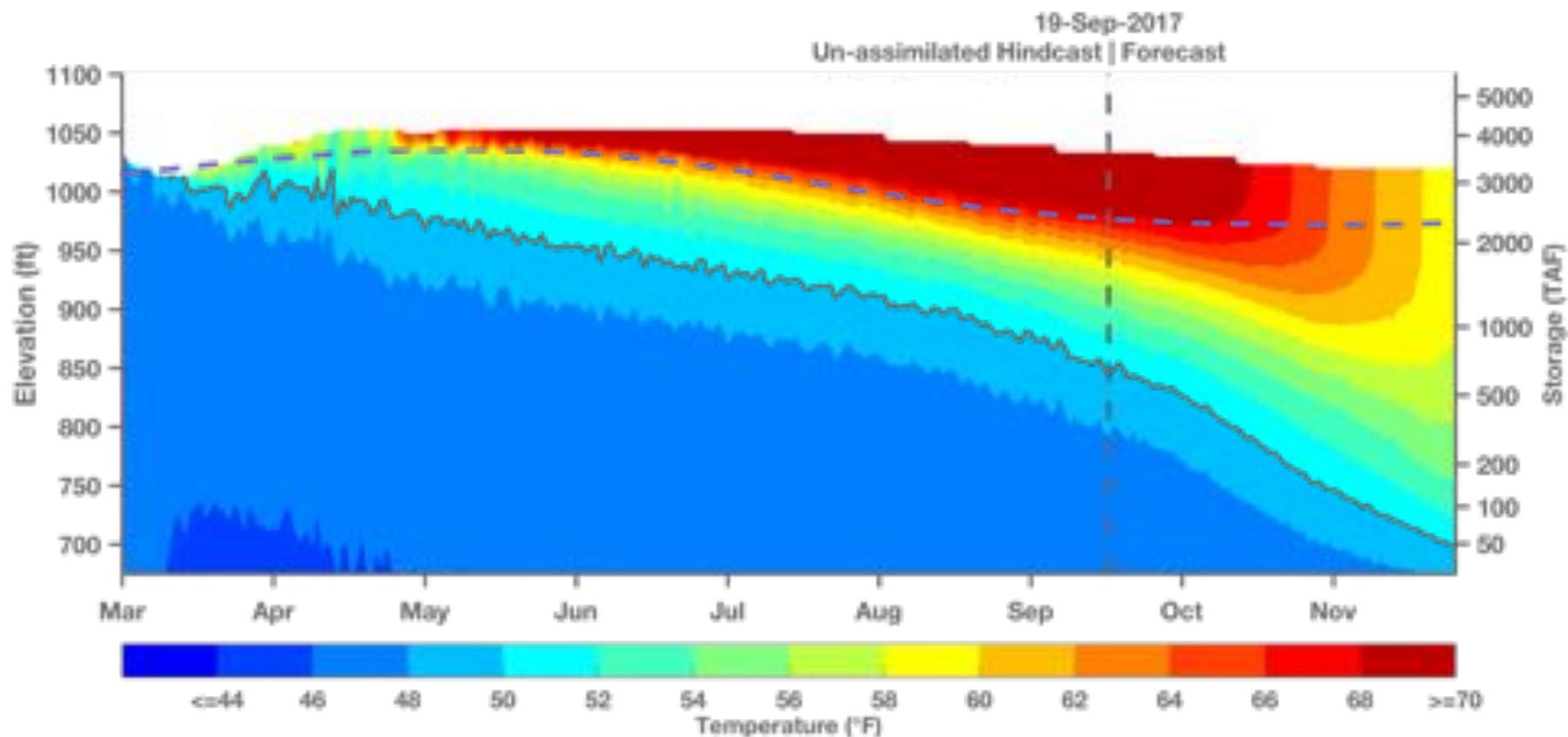
Observed and forecasted temperature inputs into Shasta Reservoir

Reservoir Temperature Profile



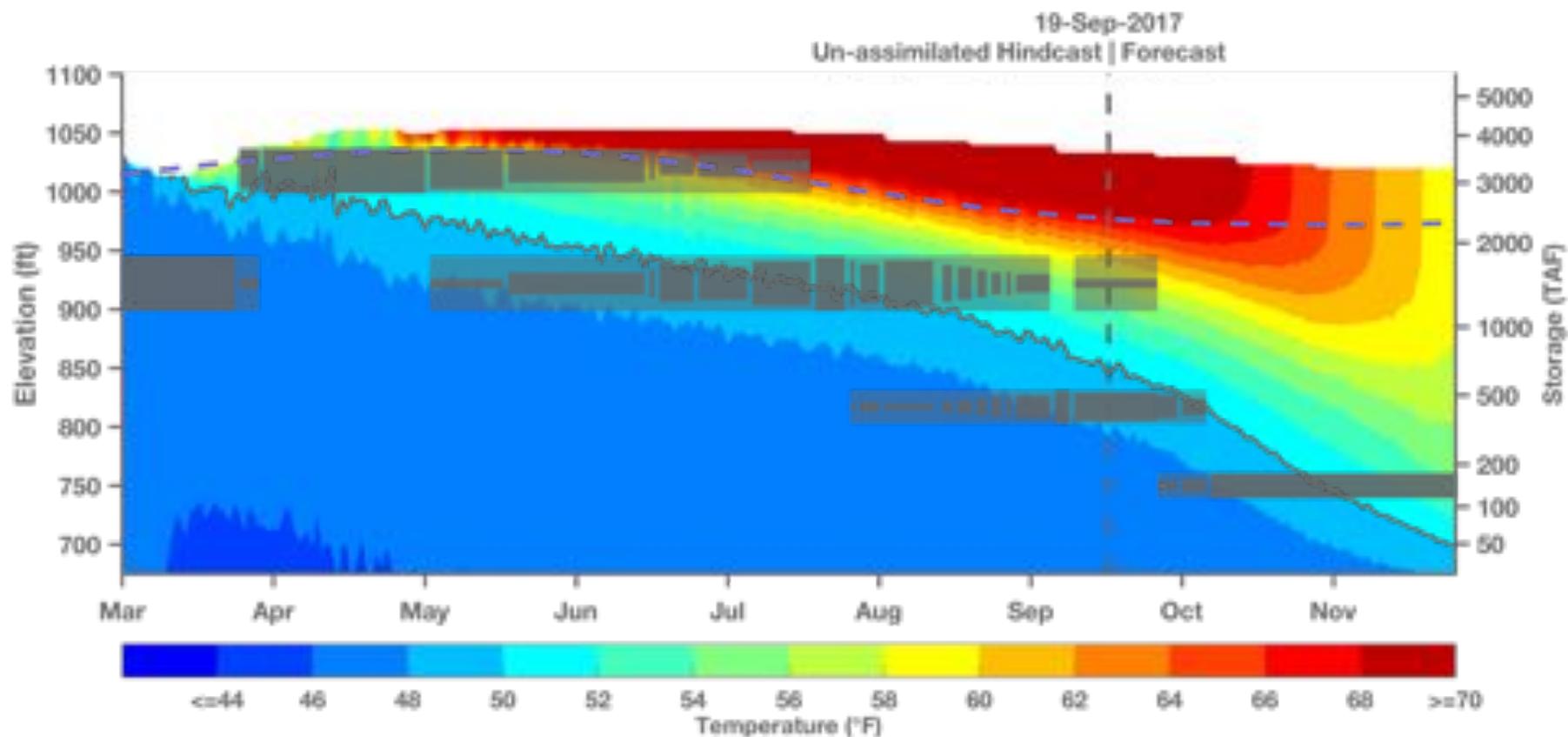
CE-QUAL-W2 model hindcast and forecasted vertical temperature profile of Shasta Reservoir, with 50 degrees Fahrenheit contour (grey line), TCD gate operations (grey boxes), and mean historical water surface elevation (blue dashed line) shown.

Reservoir Temperature Profile



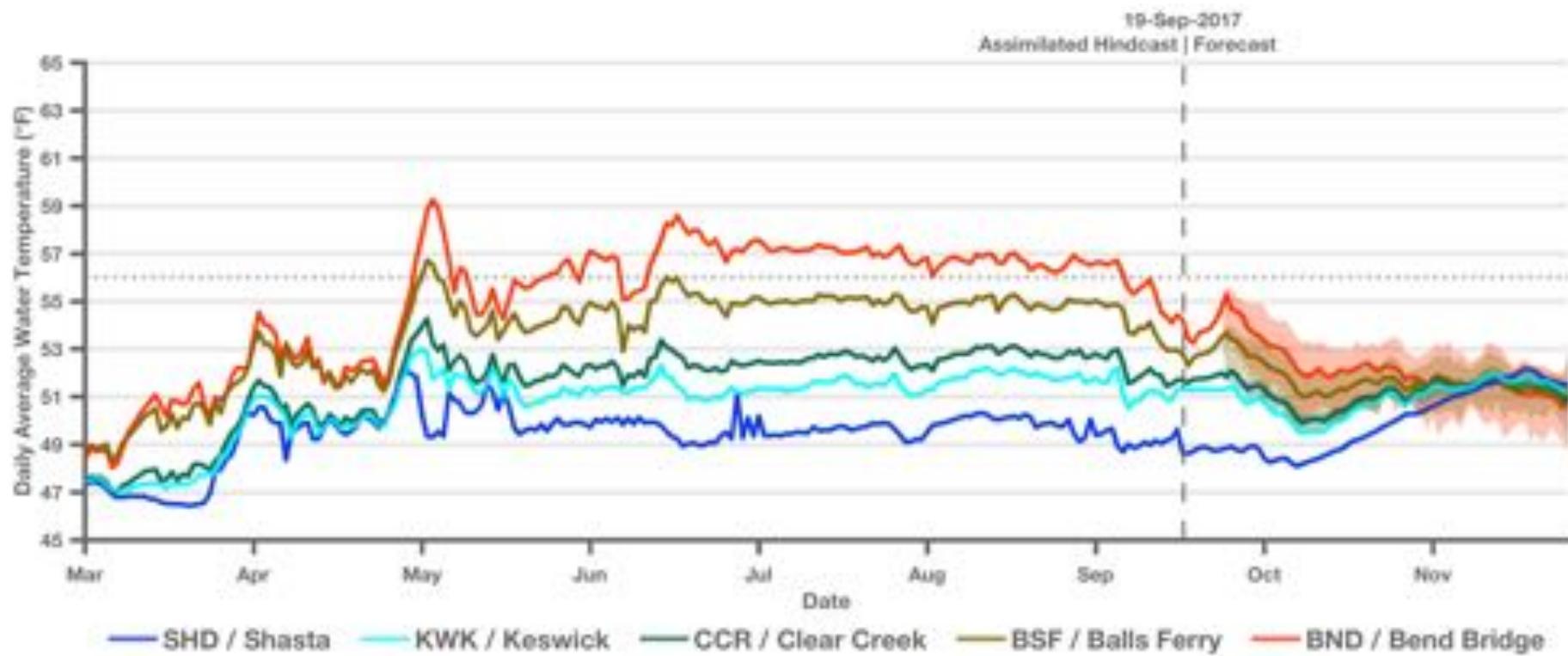
CE-QUAL-W2 model hindcast and forecasted vertical temperature profile of Shasta Reservoir, with 50 degrees Fahrenheit contour (grey line), TCD gate operations (grey boxes), and mean historical water surface elevation (blue dashed line) shown.

Reservoir Temperature Profile



CE-QUAL-W2 model hindcast and forecasted vertical temperature profile of Shasta Reservoir, with 50 degrees Fahrenheit contour (grey line), TCD gate operations (grey boxes), and mean historical water surface elevation (blue dashed line) shown.

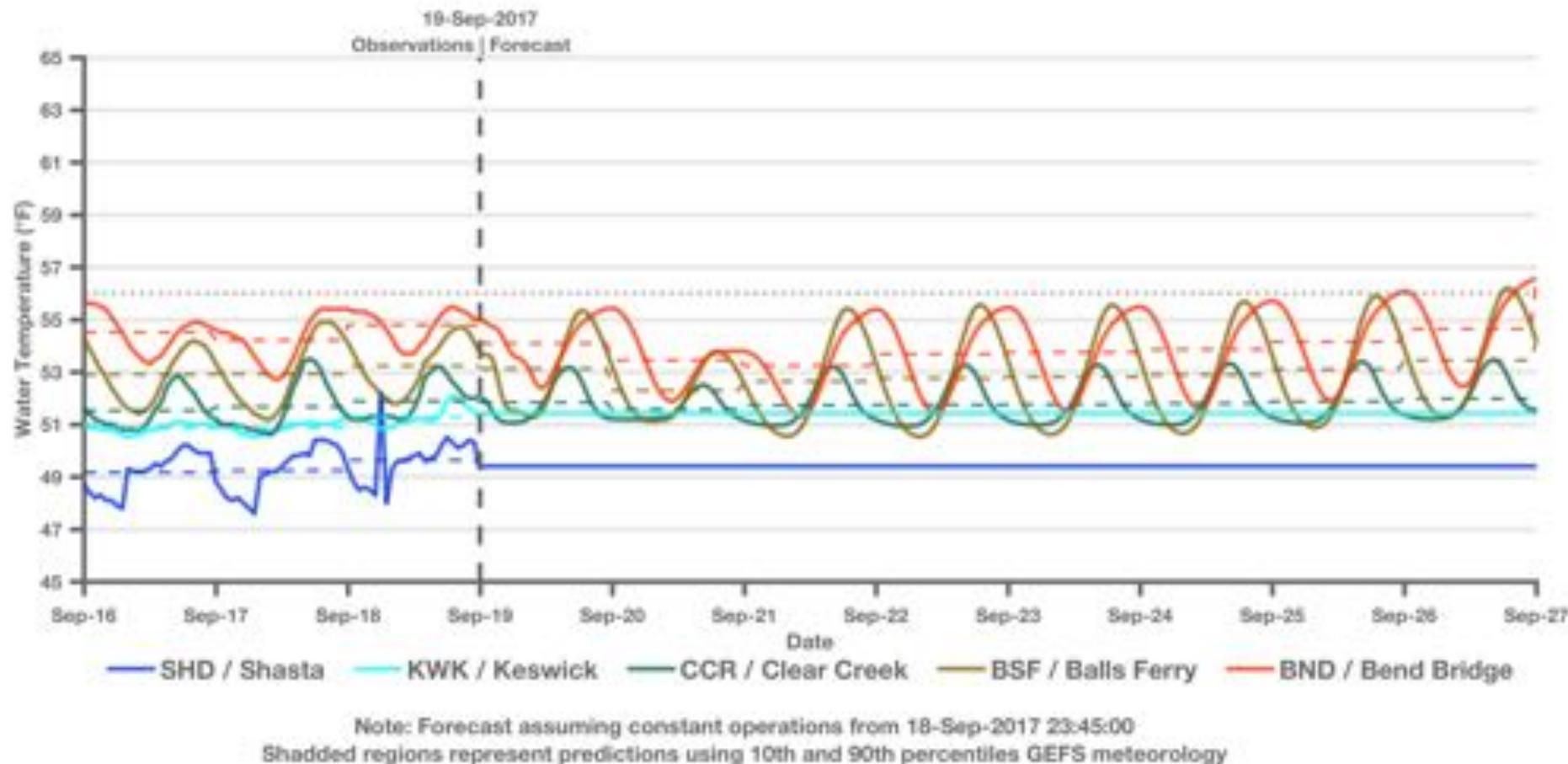
Sacramento River Temperatures Long-Term



Note: Shaded region is the min/max of daily average temperature under meteorological conditions from 1990-2015.
Forecast assuming operational scenario AUG2017 INPUT 90 OUTPUT 90 10L3MTO

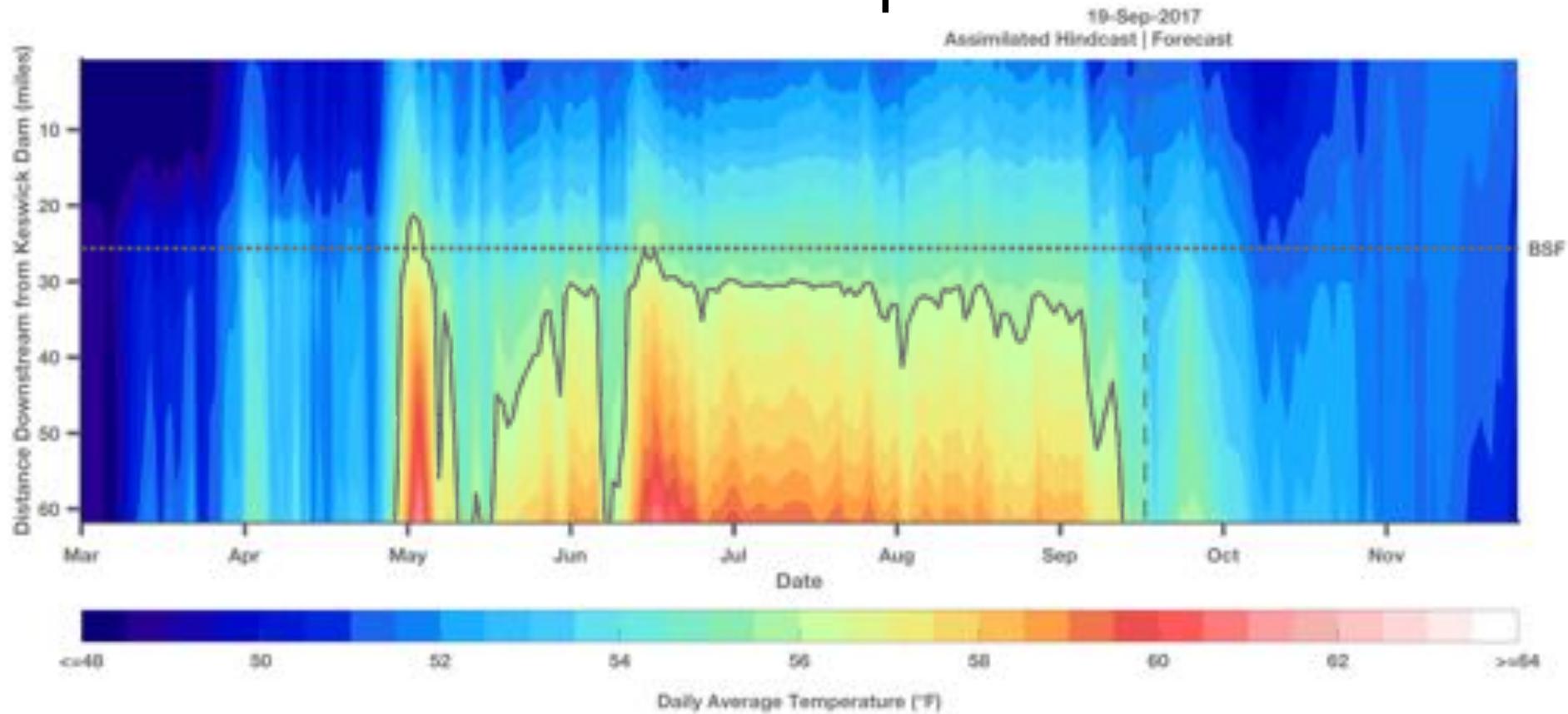
Modeled temperature time series at five locations in model domain.

Sacramento River Temperatures Short-Term



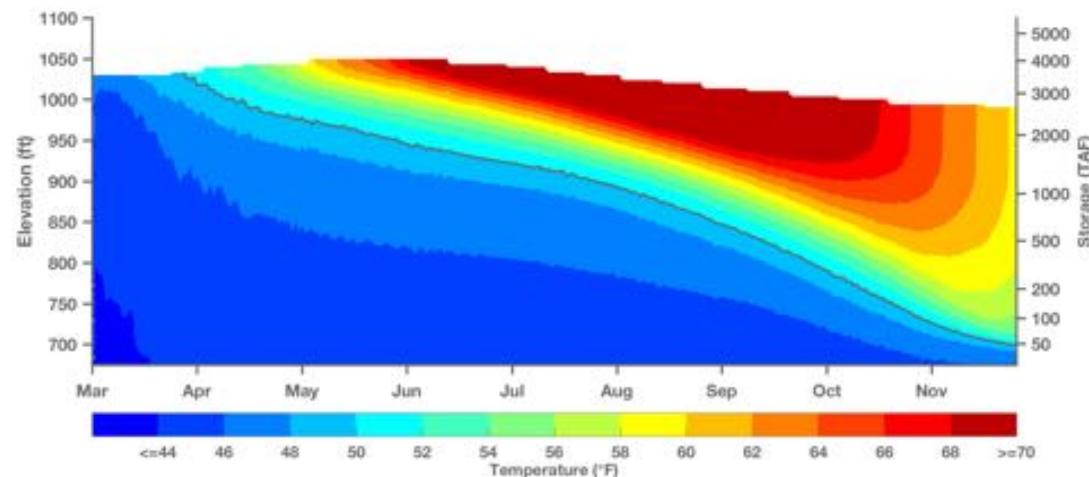
Observed and short term forecasted temperature time series at five locations in model domain.

Sacramento River Temperature Landscape

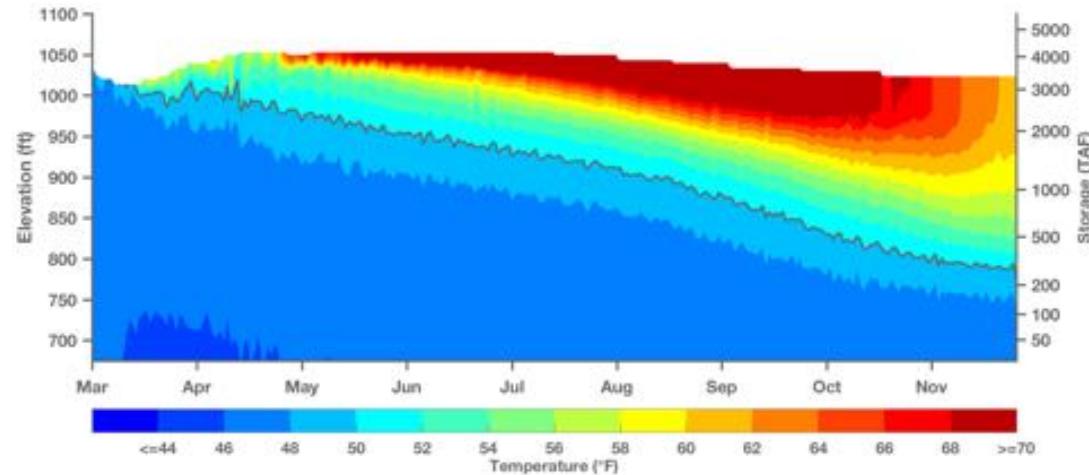


RAFT modeled temperature landscape in the Sacramento River, with 56 degrees Fahrenheit contour (grey line) and location of Balls Ferry shown.

Model performance - reservoir

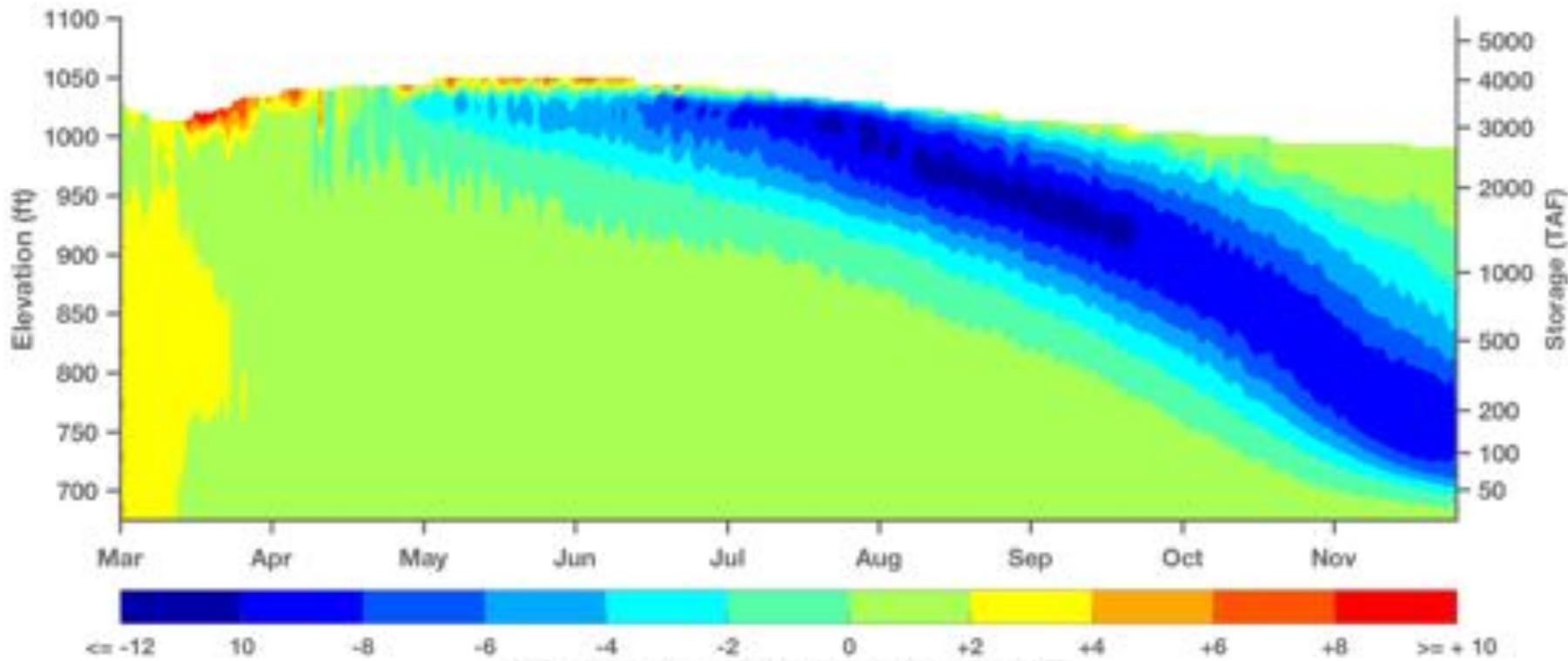


Predicted profile as
of March 1, 2017



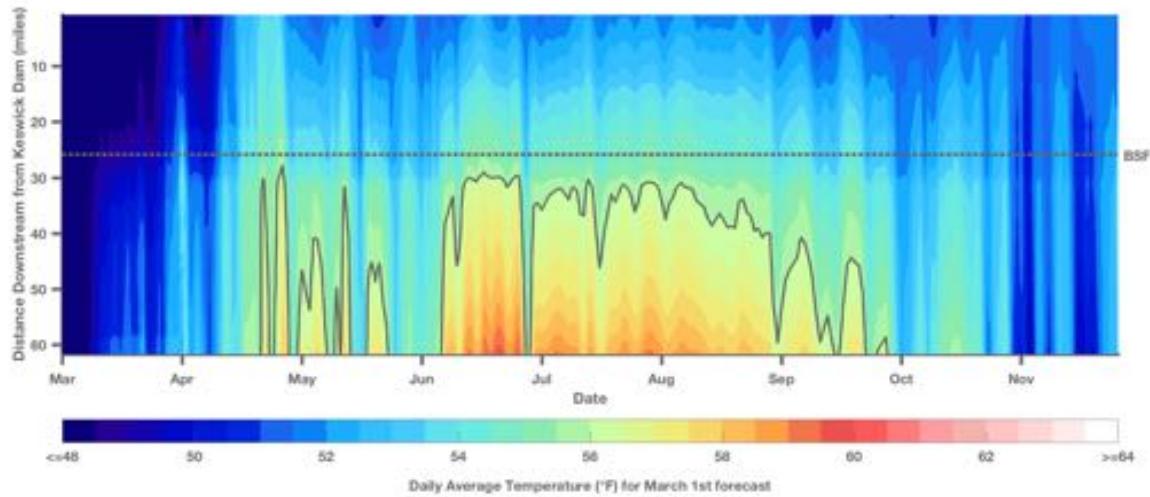
Observed profile as of
November 27, 2017

Model performance - reservoir

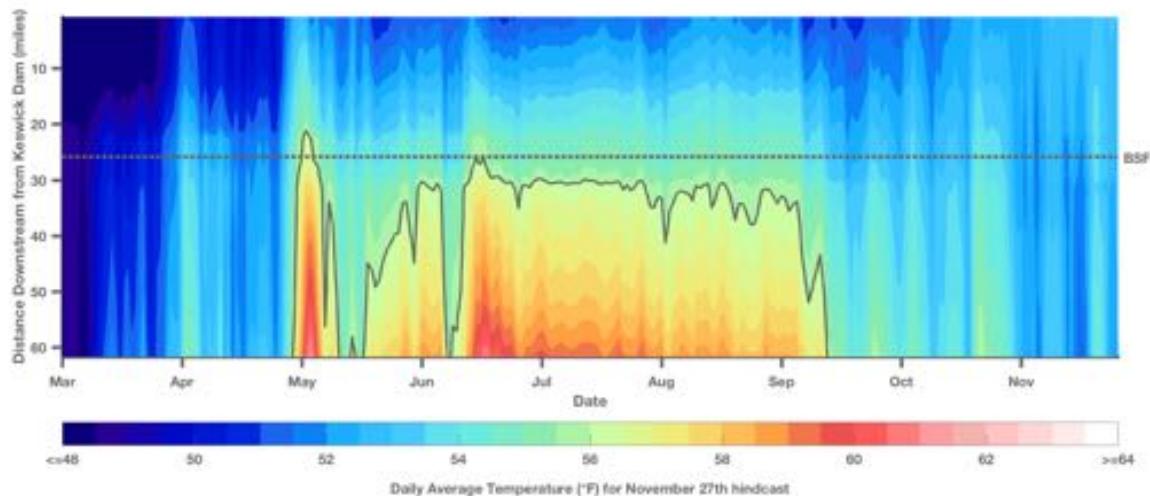


Difference between daily average temperatures ($^{\circ}\text{F}$)
from of March 1, 2017 and November 27, 2017

Model performance - river

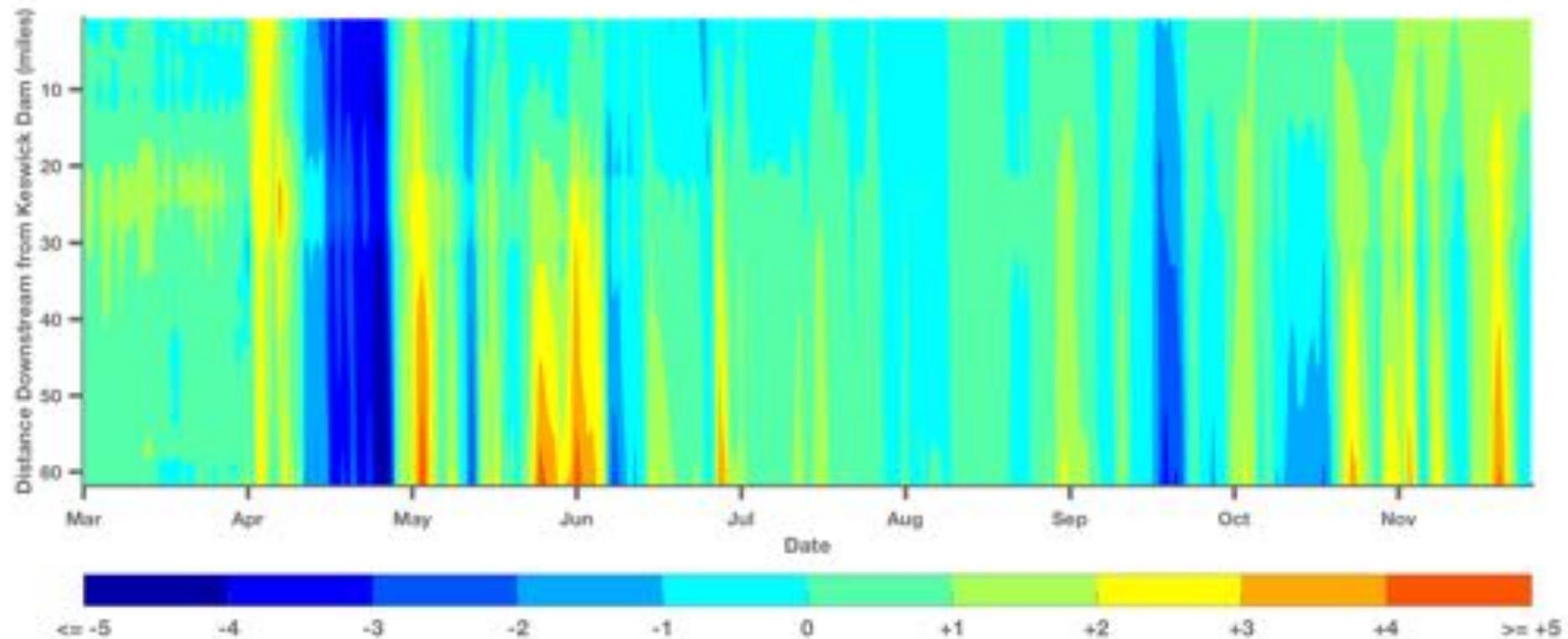


Predicted landscape
as of March 1, 2017



Observed landscape
as of November 27,
2017

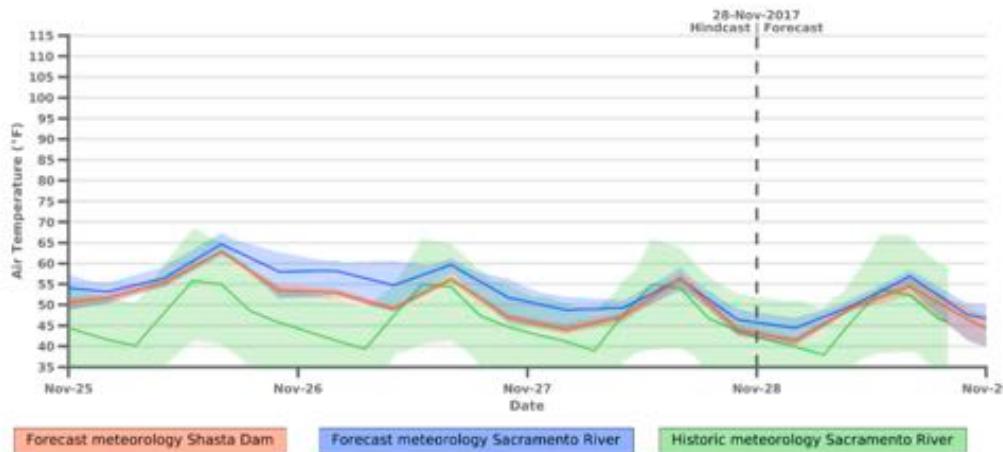
Model performance - river



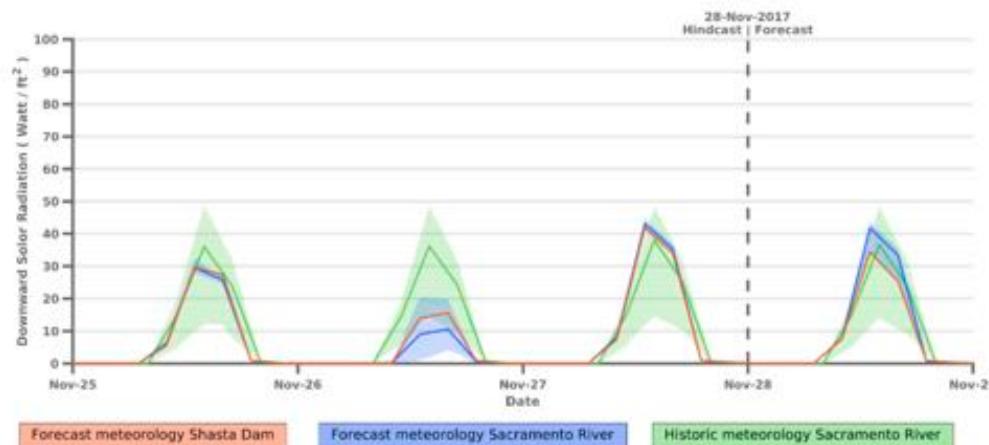
Difference between daily average temperatures ($^{\circ}\text{F}$) from of
March 1, 2017 and November 27, 2017 model runs

Meteorological Data

Air Temperature



Downward Solar Radiation

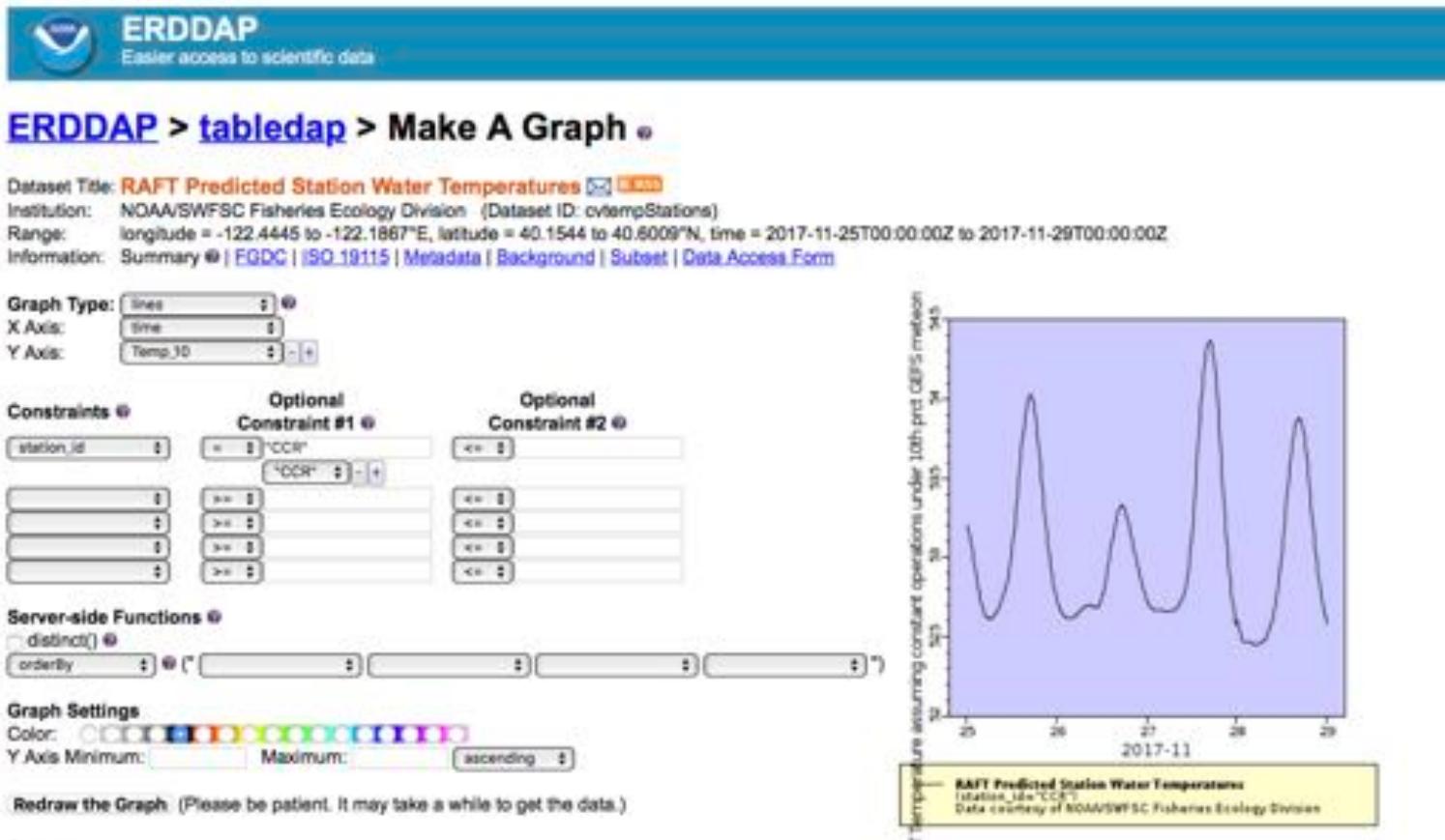


Air Temperature

Global Forecast System (GFS) and the North American Regional Reanalysis (NARR)

Solar Radiation

Downloading Data



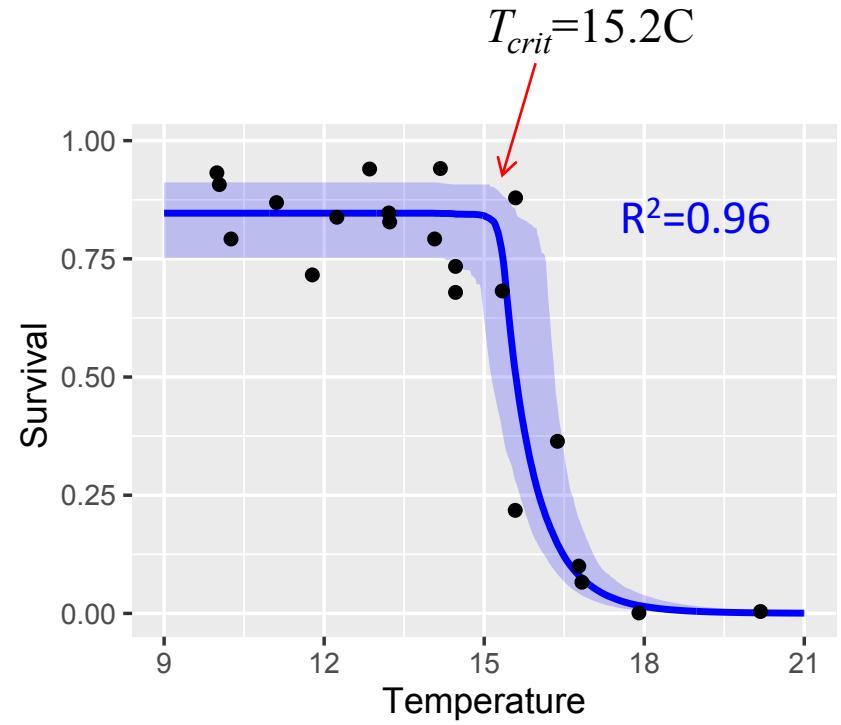
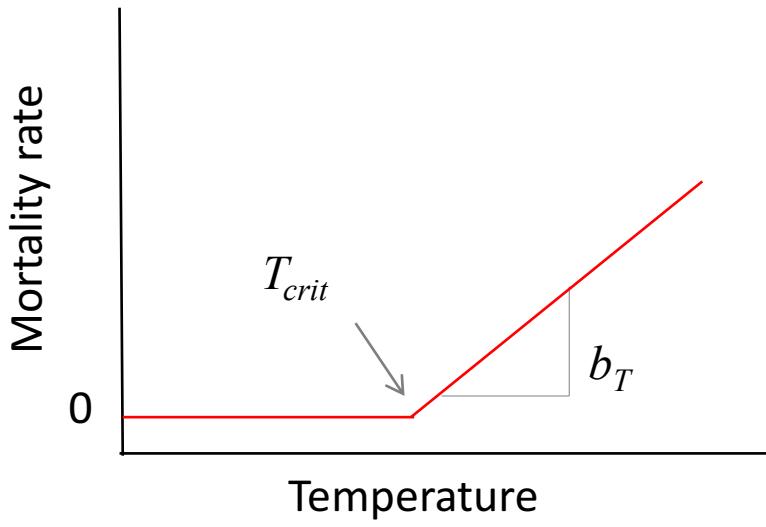
Linking Physical and Biological Models

“The development of methods that explicitly link the success or failure of achieving desired temperatures, flows and other physical targets to the biological/ecological responses of the listed species is the only way that the intended goals of the RPA Actions can be assessed in a scientific context.”

Thermal Tolerance Model

$$h_i = b_T \max(T_i - T_{\text{crit}}, 0)$$

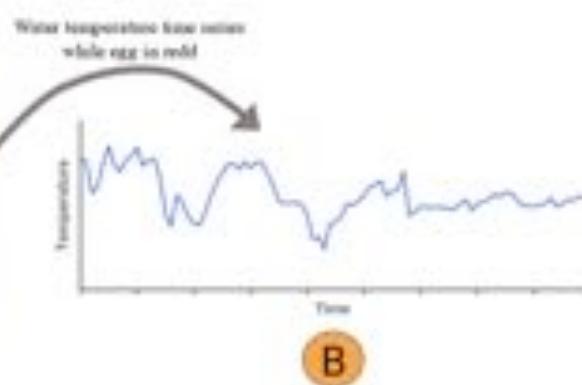
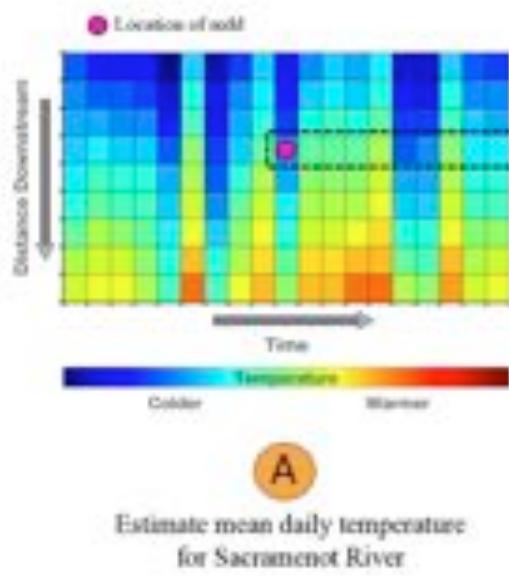
$$M_T = 1 - \prod_{i=1}^n \exp(-h_i)$$



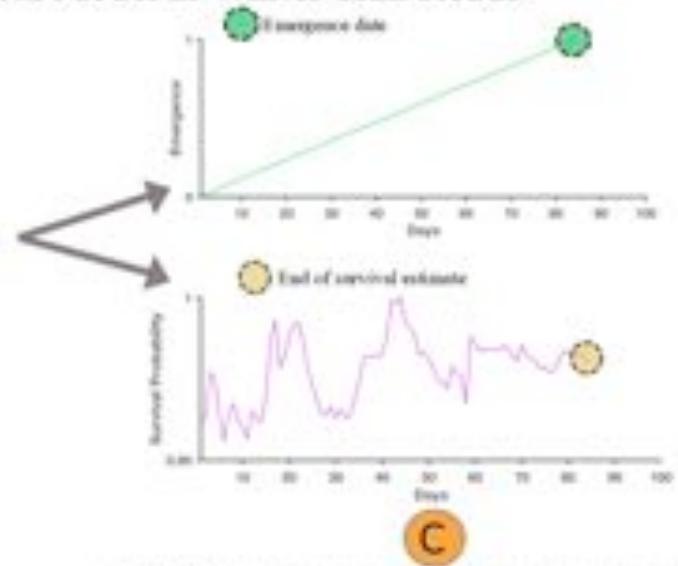
Data from: Combs and Burrows 1957,
Jenson and Groot 1991, USFWS 1999

How we apply the model

Conceptual Diagram of Temperature-Dependent Egg Survival Model in Winter-Run Redds



Estimate mean daily temperature for a given redd location over time

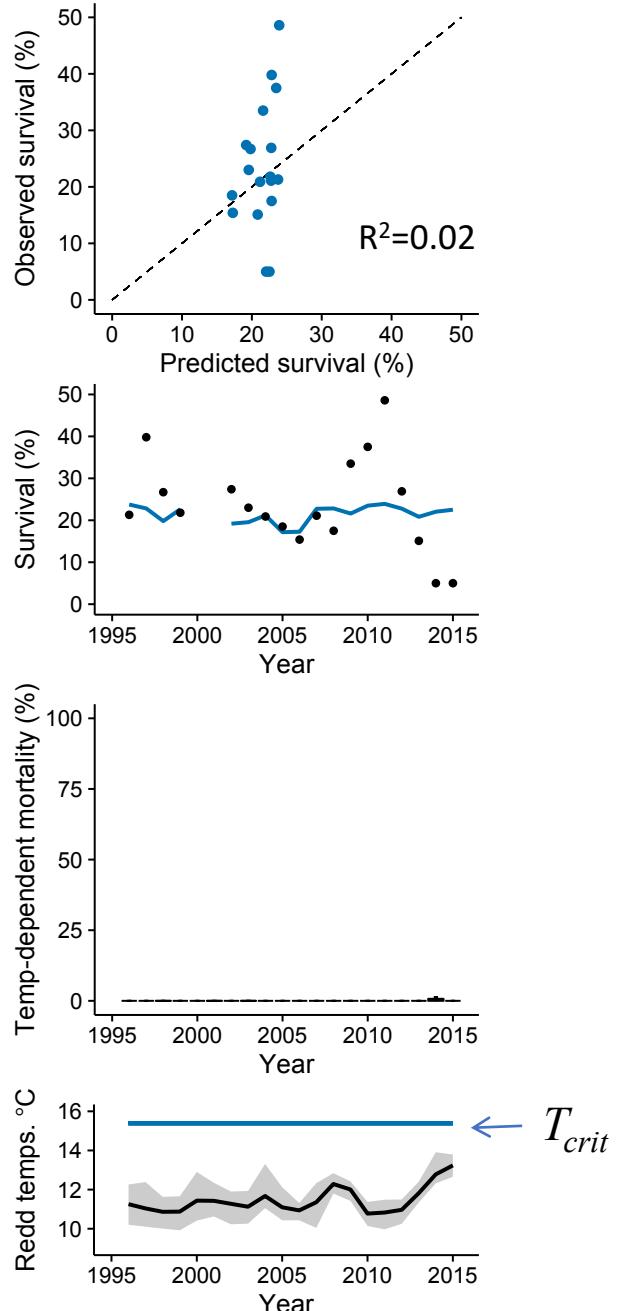


Testing the lab model

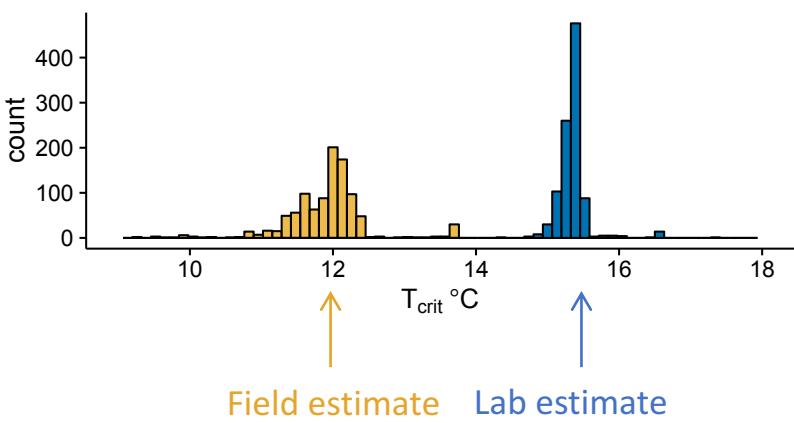
Why so bad?

- H1: Factors other than temperature drive annual variation in survival
- H2: Thermal tolerance in the field differs from the lab

Test: rerun analysis, but estimate thermal tolerance parameters using field data

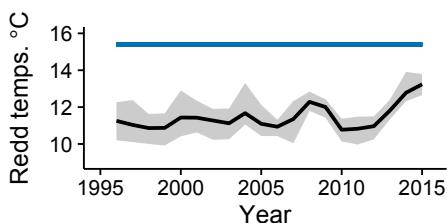
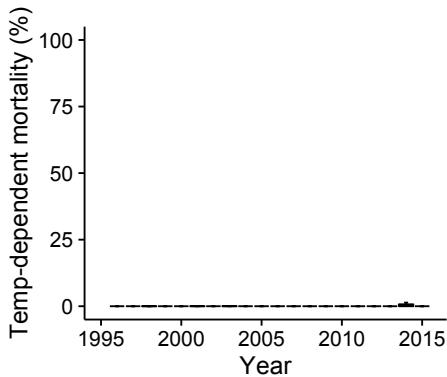
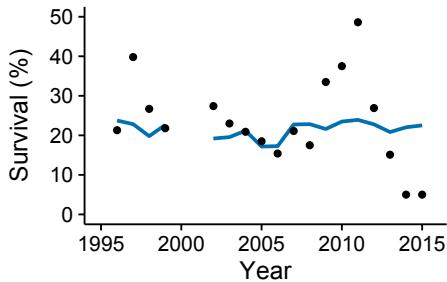
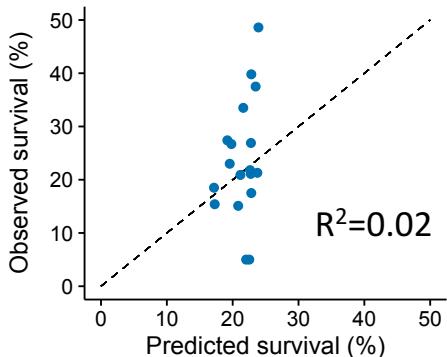


Lab vs. field

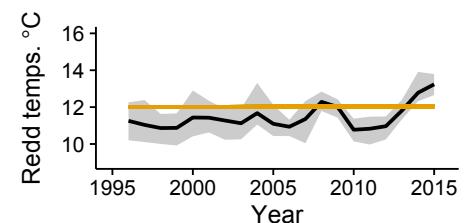
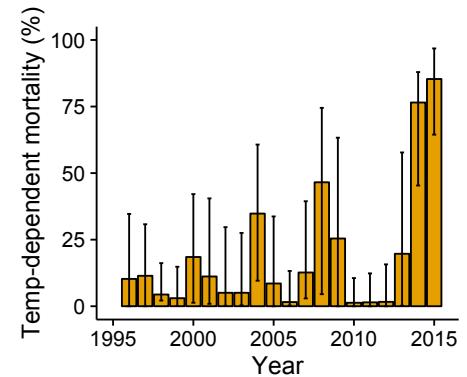
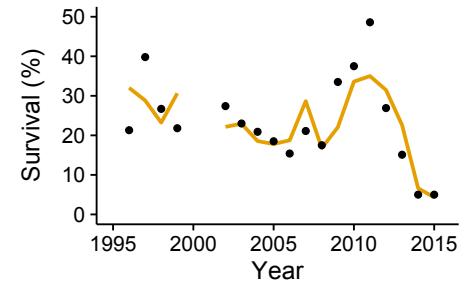
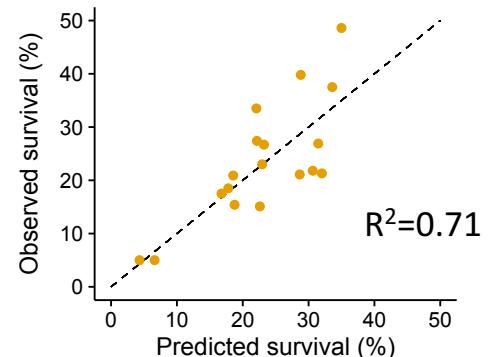


Thermal tolerance in the field
3°C lower than in the lab!

Lab-parameterized model



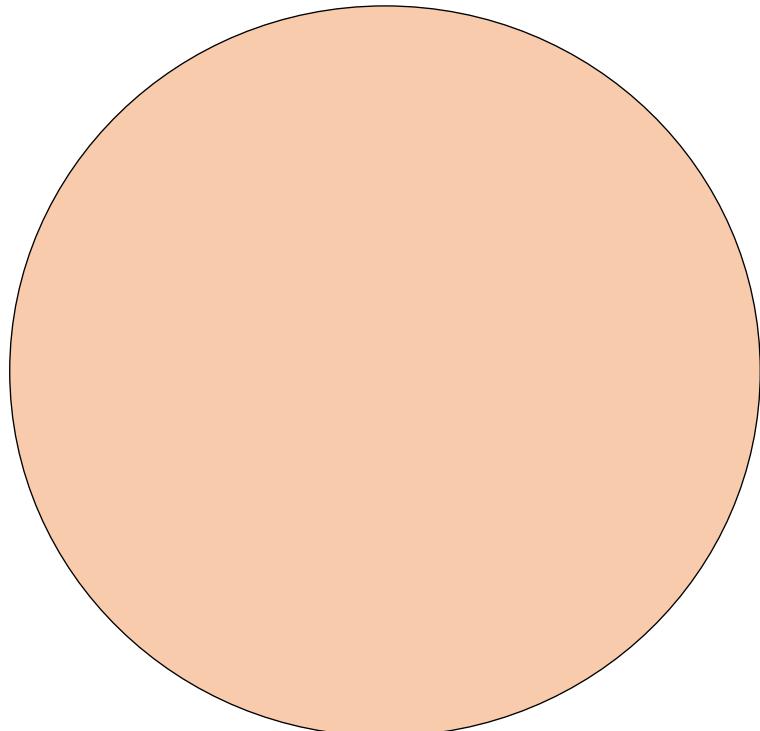
Field-parameterized model



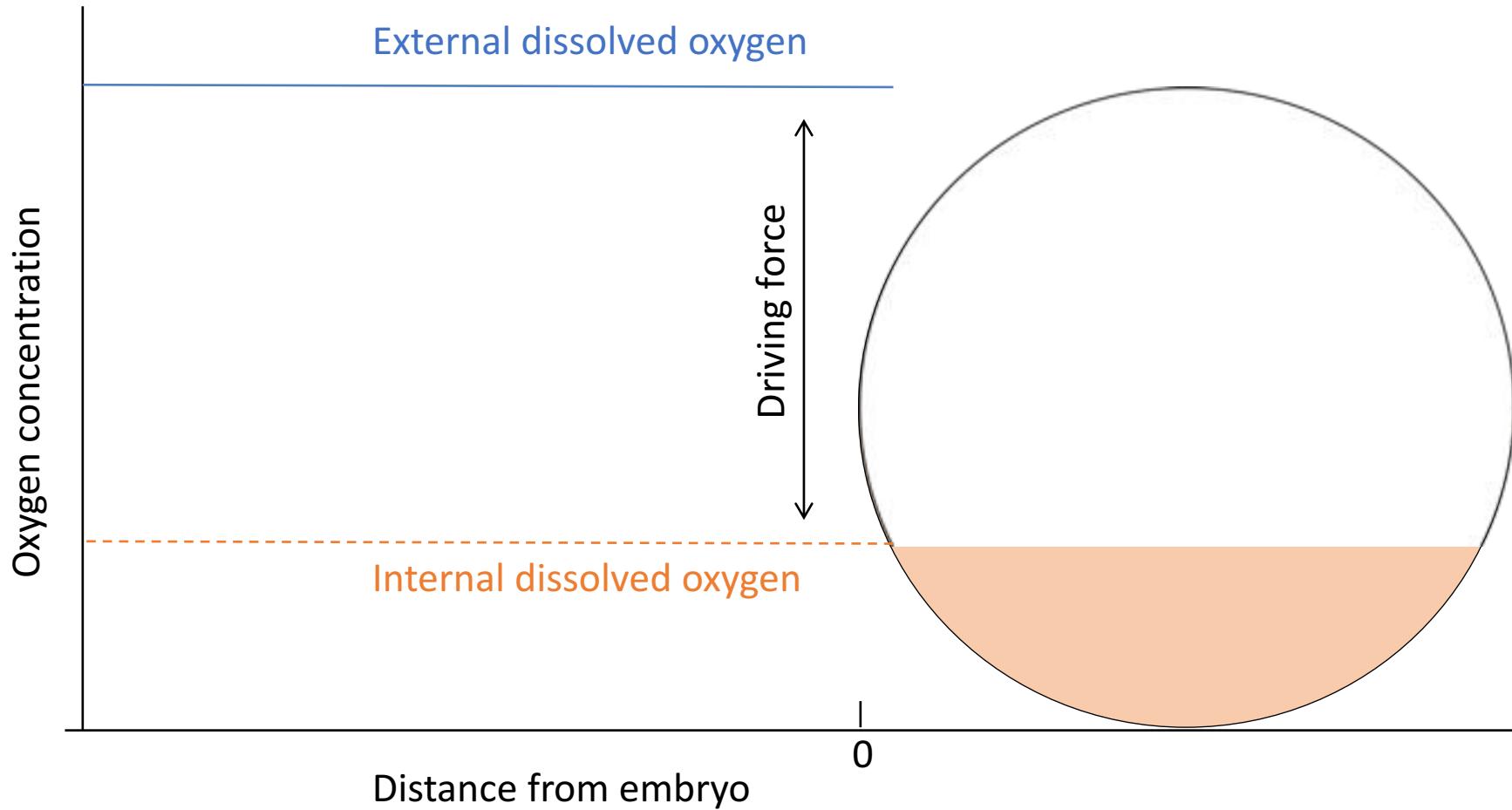
Oxygen Limitation?

Embryos

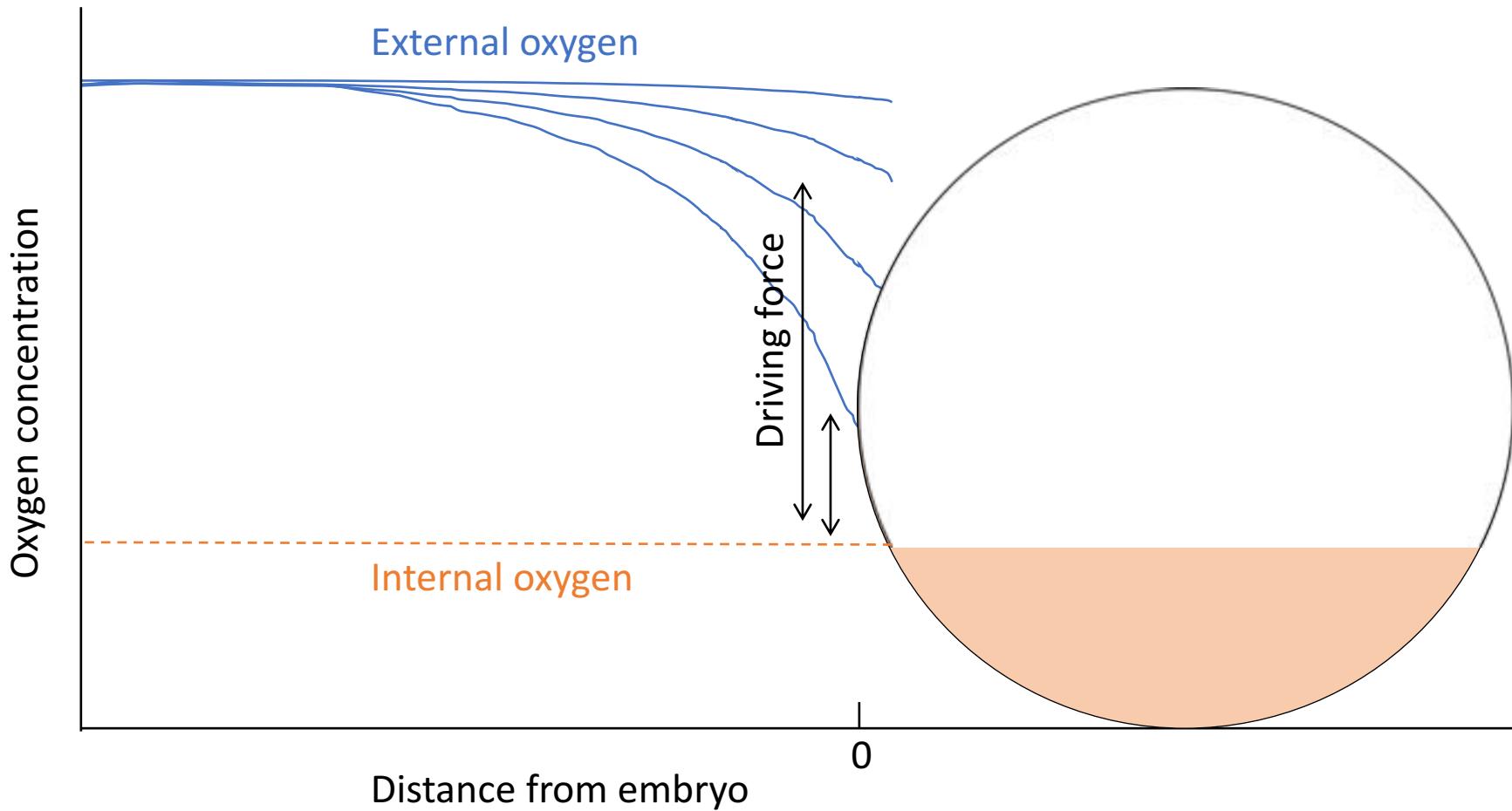
- Can't move
- High mass-specific oxygen demand
- Supply dependent on environment
 - DO
 - Flow



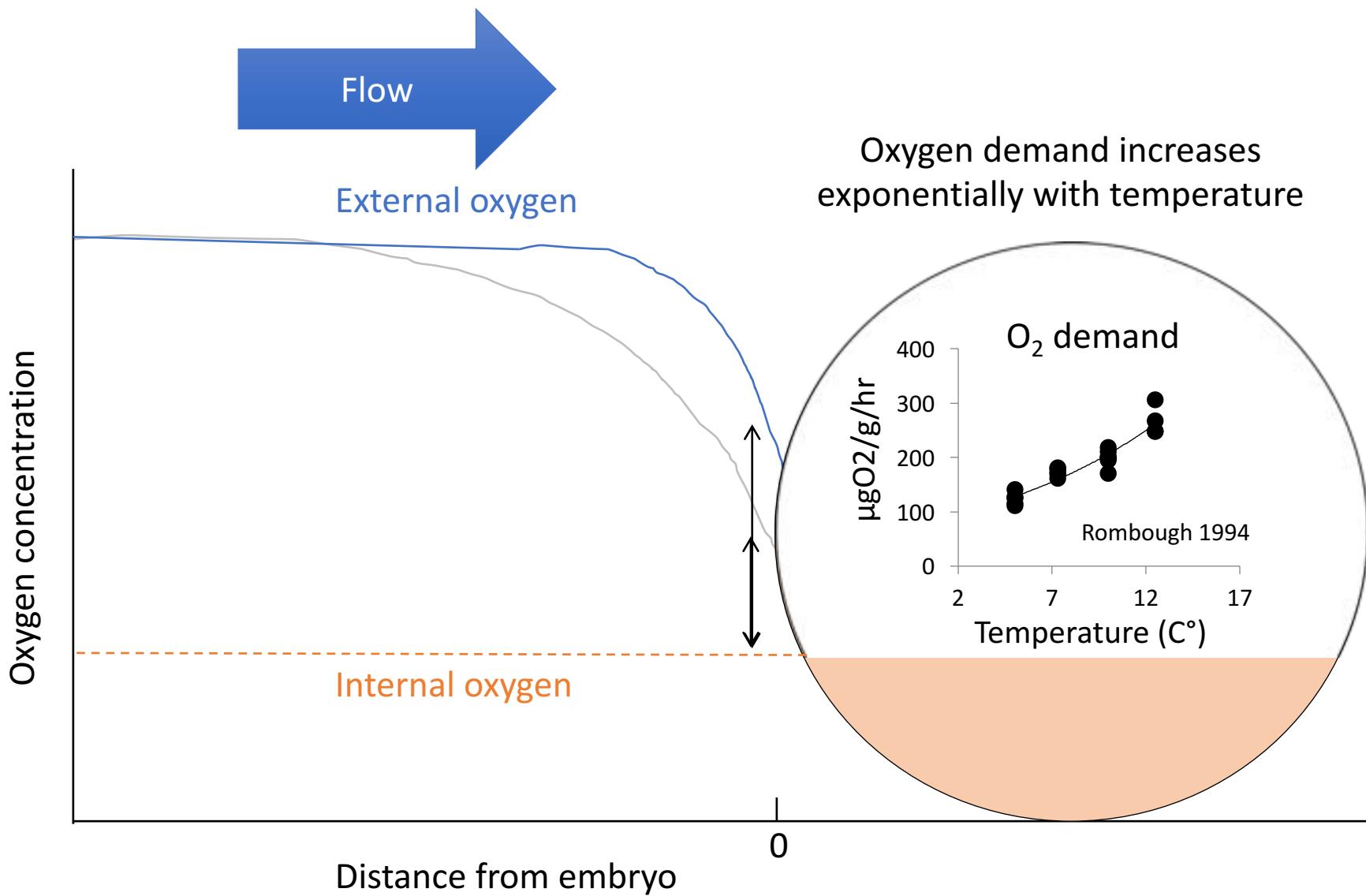
Oxygen Limitation?



Oxygen Limitation?

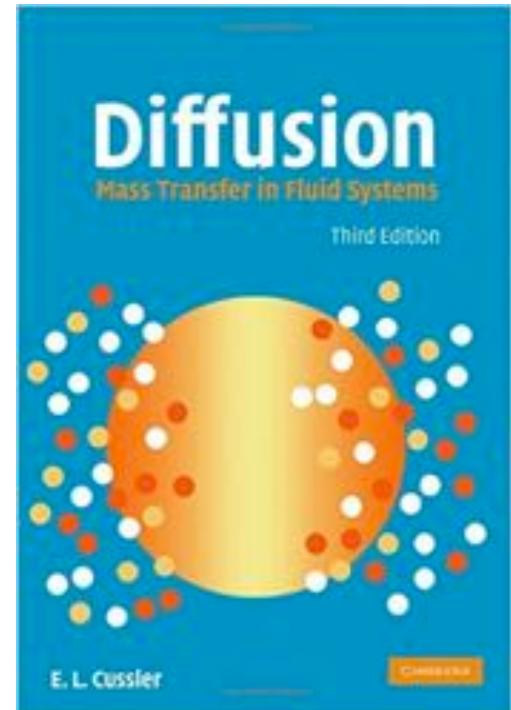


Oxygen Limitation?



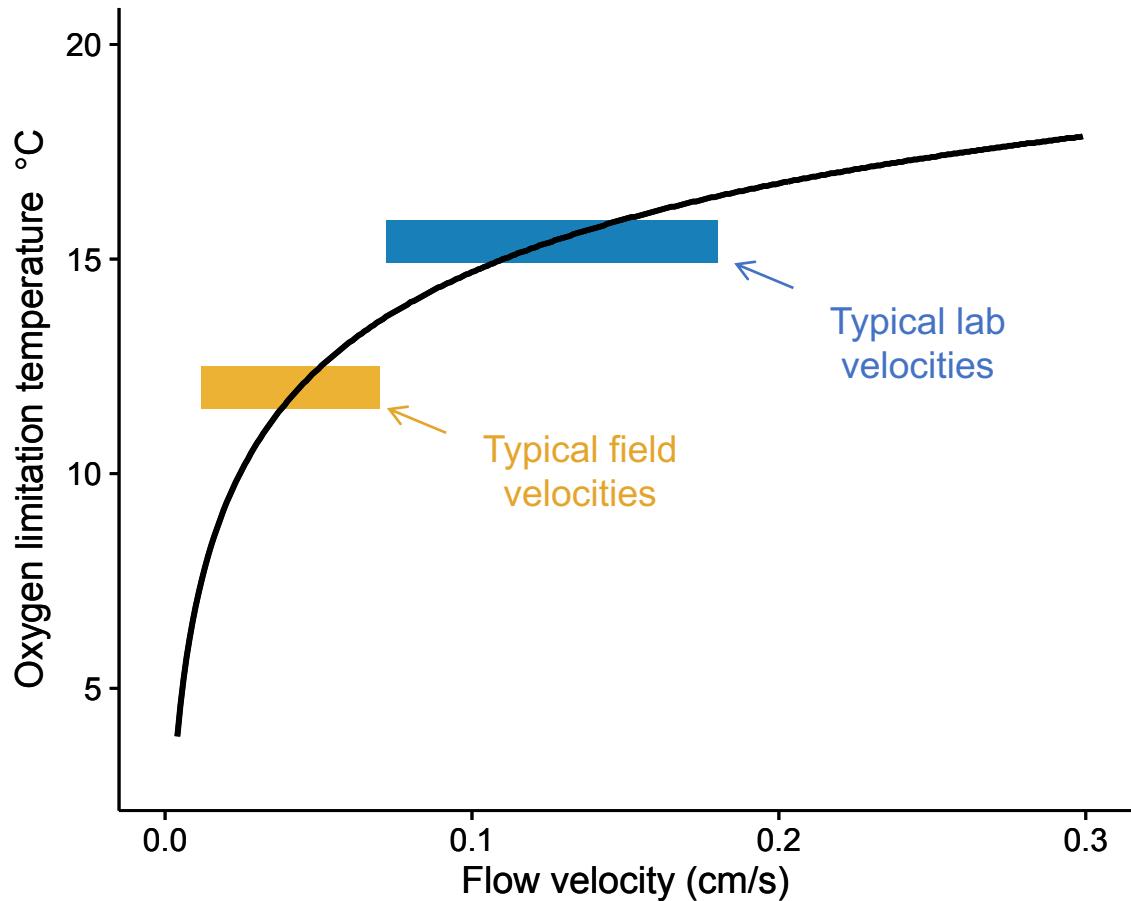
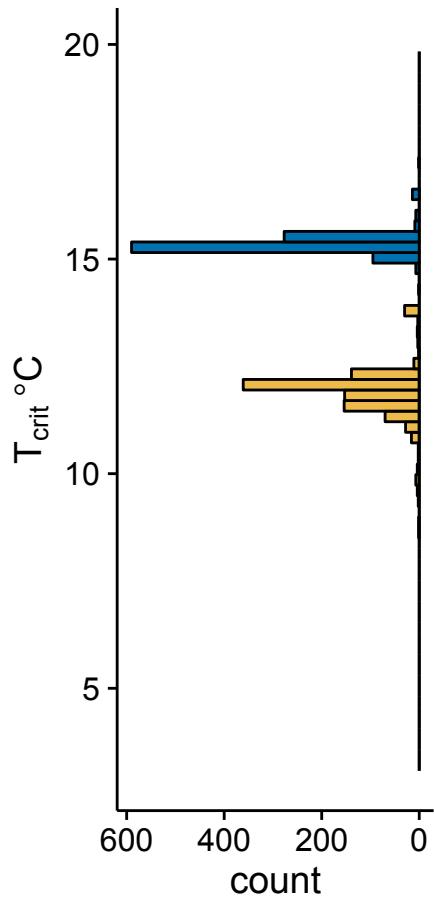
Mass Transfer Theory

- Physics worked out long ago, but rarely applied
- Can calculate thermal tolerance function of flow, DO
- Few parameters needed
 - Biological (4)
 - Temp-dependent metabolic rate (2)
 - Critical oxygen tension and egg conductance (2)
 - Physical (2)
 - Look up in a textbook



$$U_{crit} = \frac{\mu \left(\frac{5N\delta Rk_e}{2D(4\pi R^2 k_e (P_e - P_i^*) - N\delta)} + \frac{5}{2} \right)^2}{2R \left(\frac{\mu}{D} \right)^{2/3}}$$

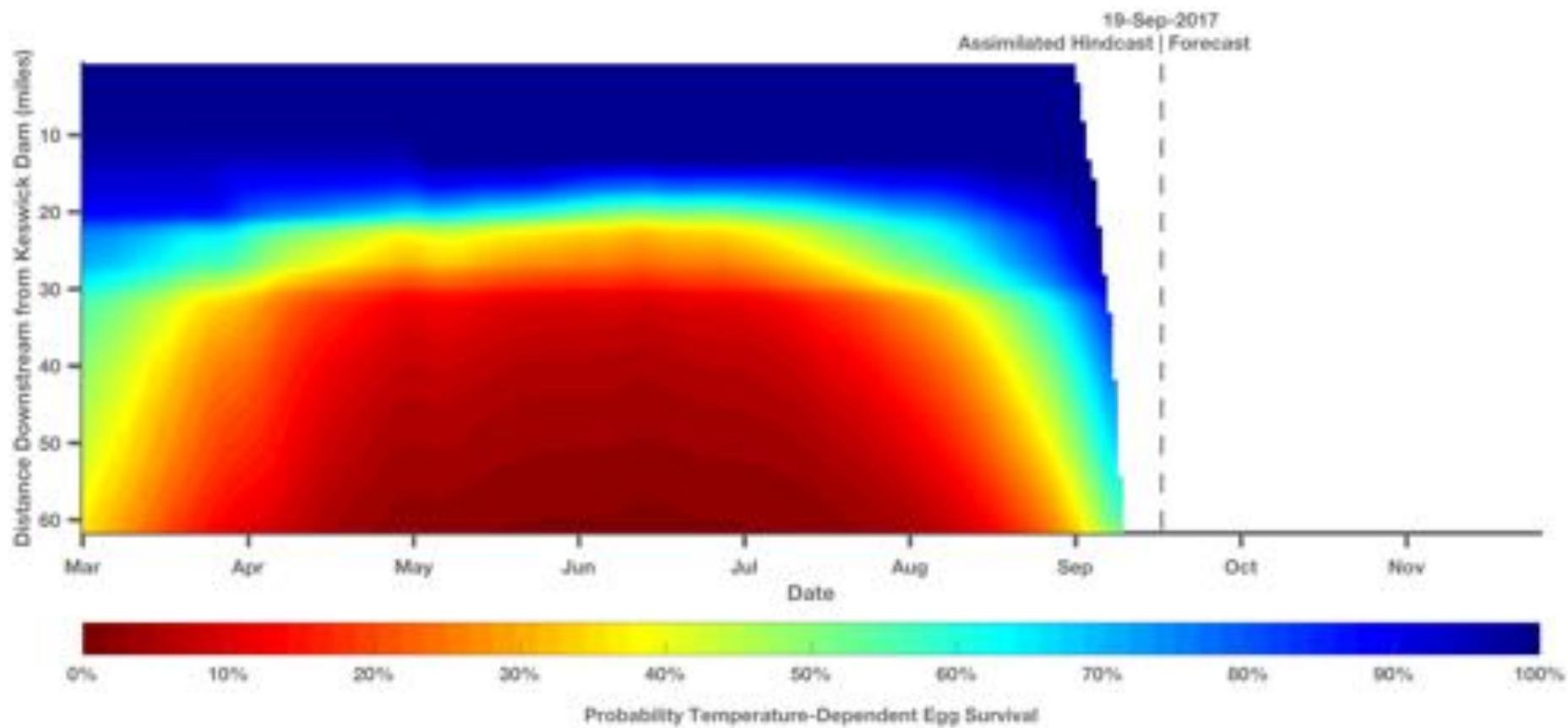
Lab vs Field



Model Assumptions

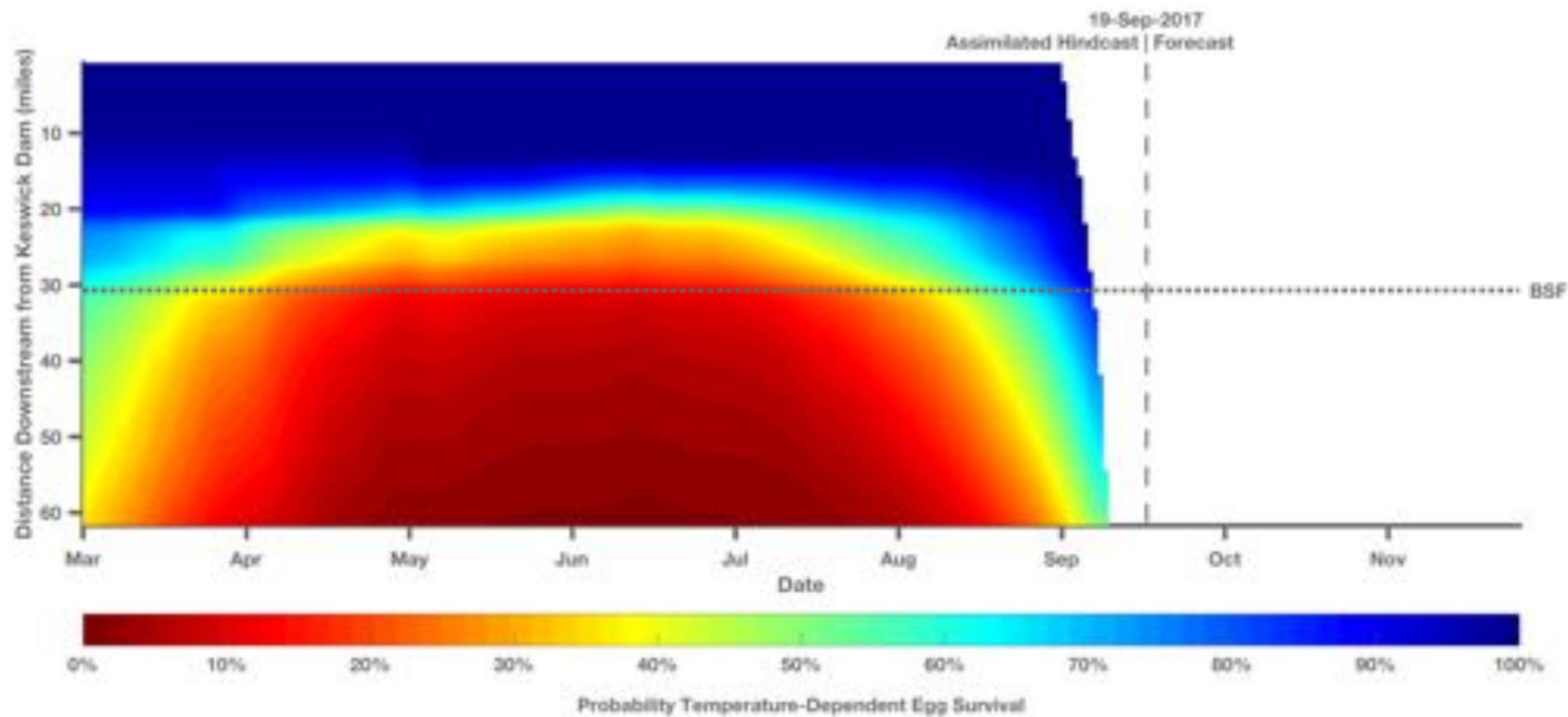
- Constant thermal tolerance parameters throughout embryonic stage
- Other sources of mortality grouped into background survival parameter
- Temp-dependent mortality occurs only during embryonic stage

Survival at the Landscape Scale



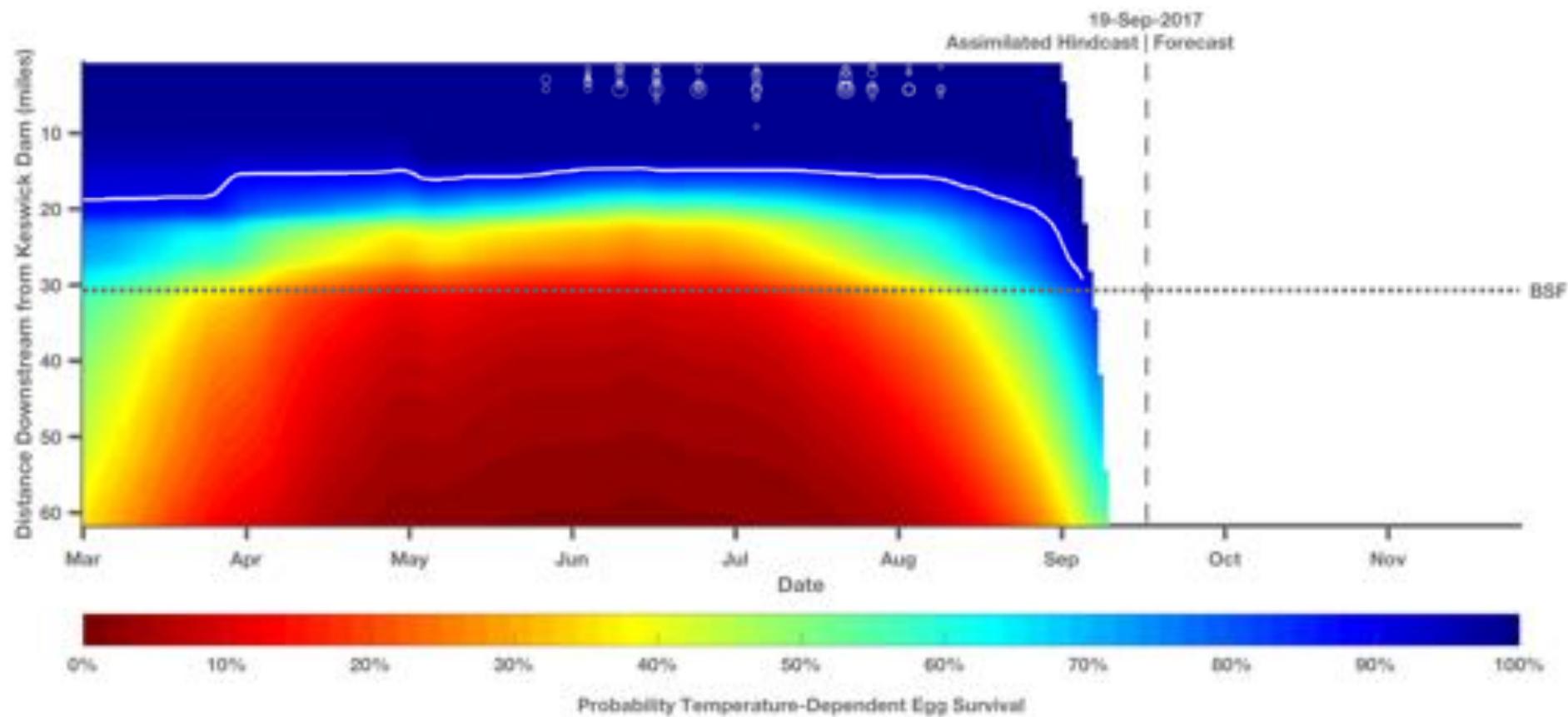
Modeled temperature-dependent egg survival landscape in the Sacramento River, with 90 percent survival contour (white line), redd distribution in 2015 (white circles), and location of Balls Ferry shown.

Survival at the Landscape Scale



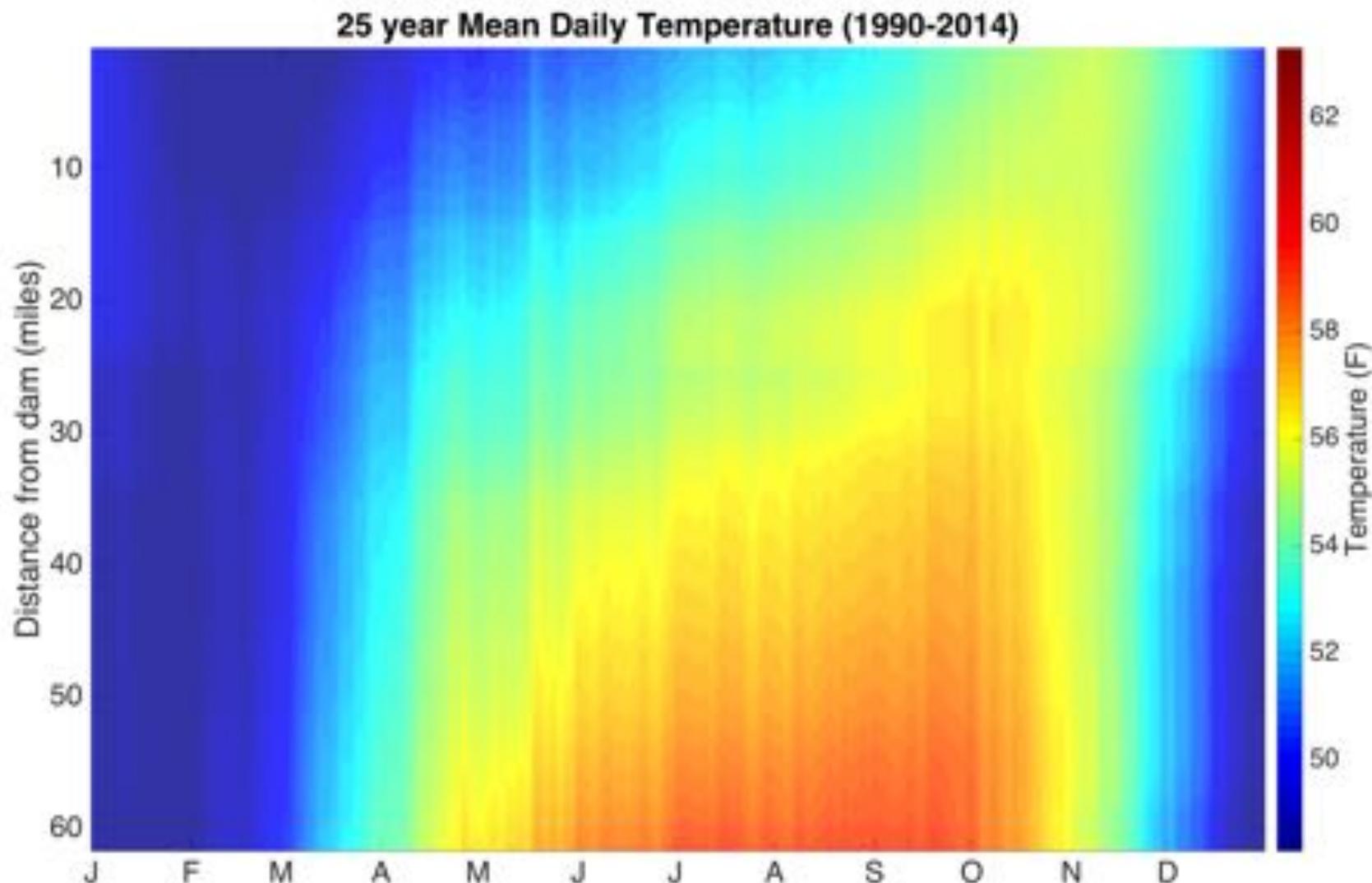
Modeled temperature-dependent egg survival landscape in the Sacramento River, with 90 percent survival contour (white line), redd distribution in 2015 (white circles), and location of Balls Ferry shown.

Survival at the Landscape Scale

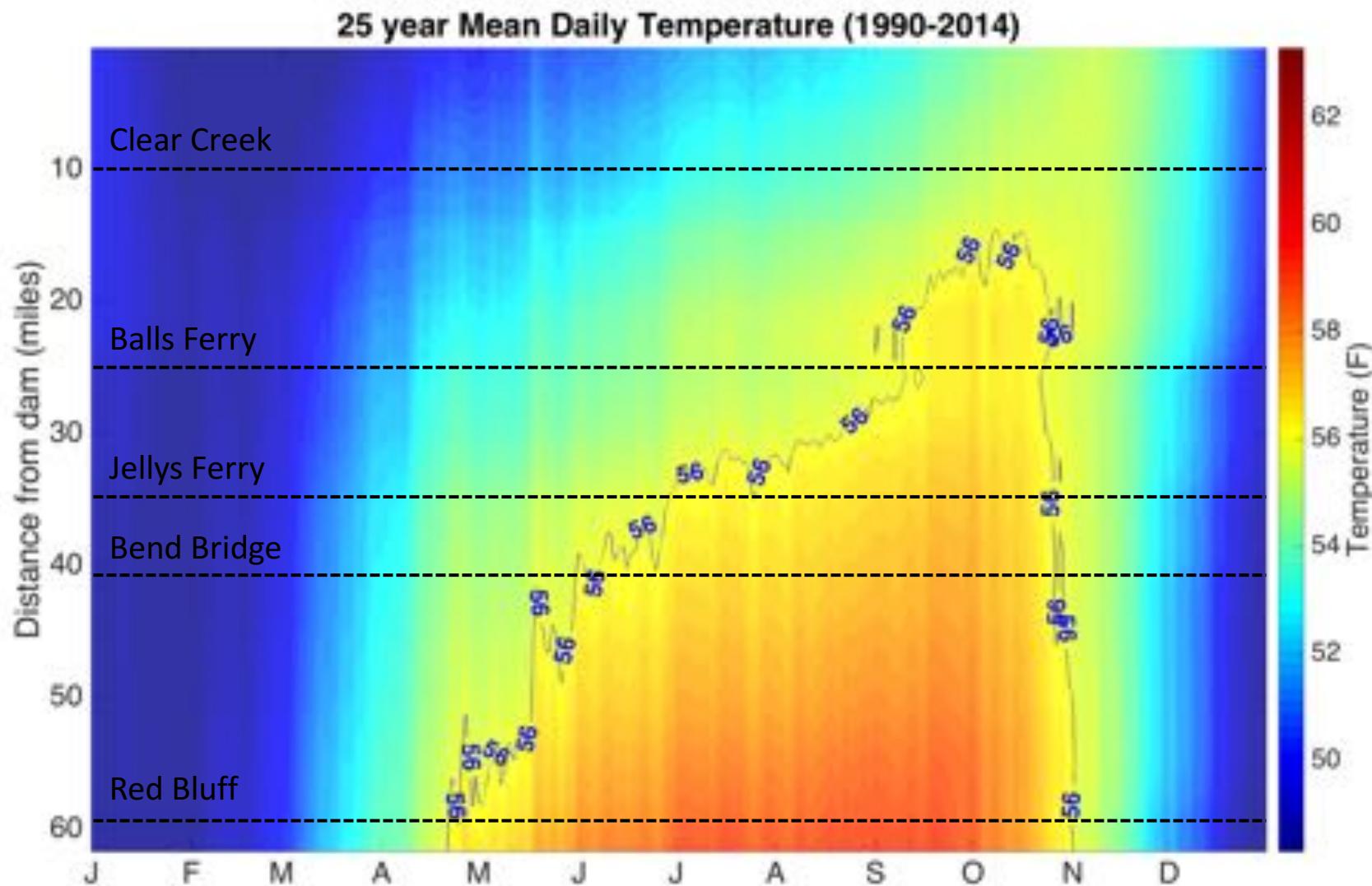


Modeled temperature-dependent egg survival landscape in the Sacramento River, with 90 percent survival contour (white line), redd distribution in 2015 (white circles), and location of Balls Ferry shown.

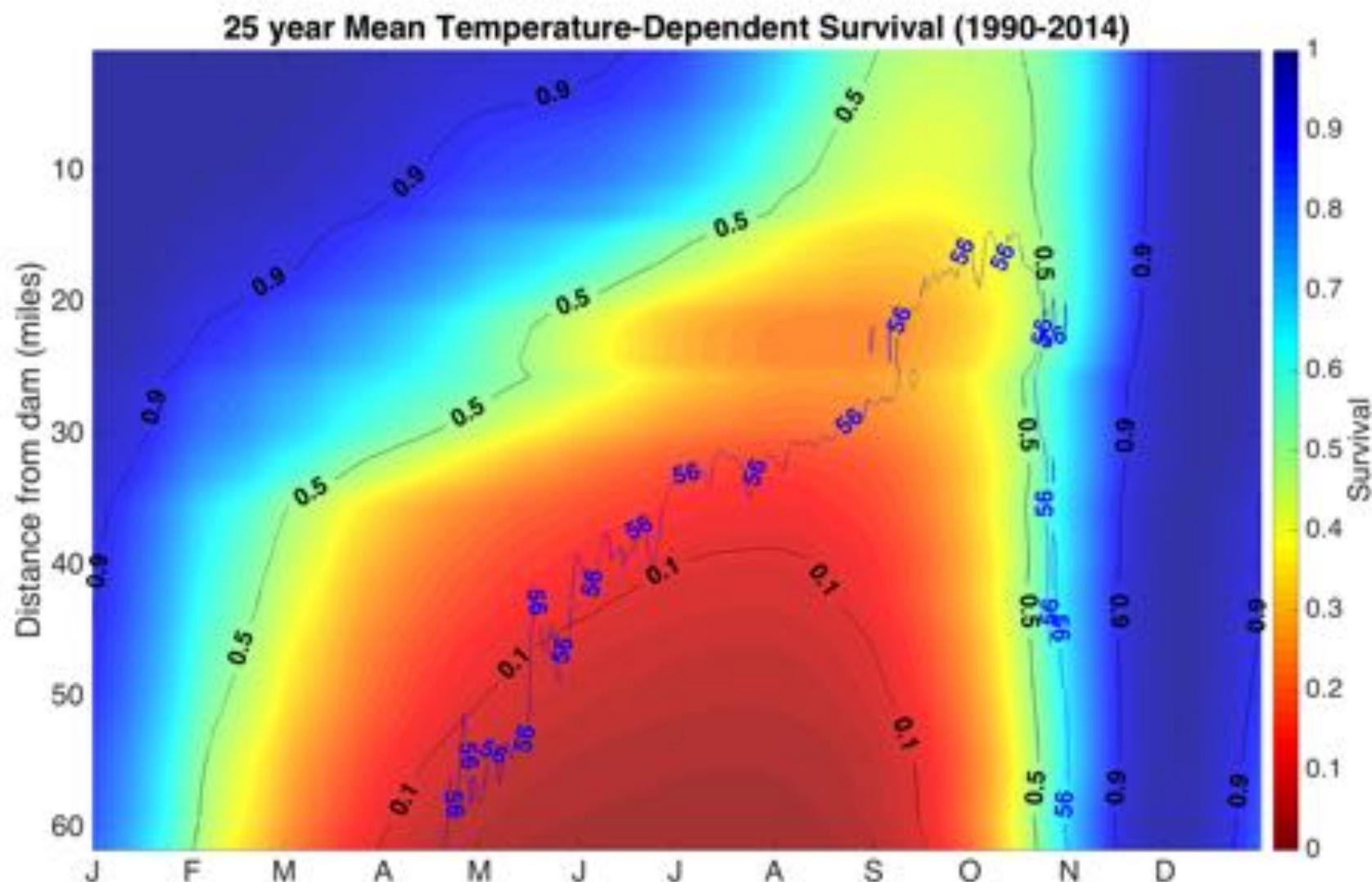
Temperature Landscape



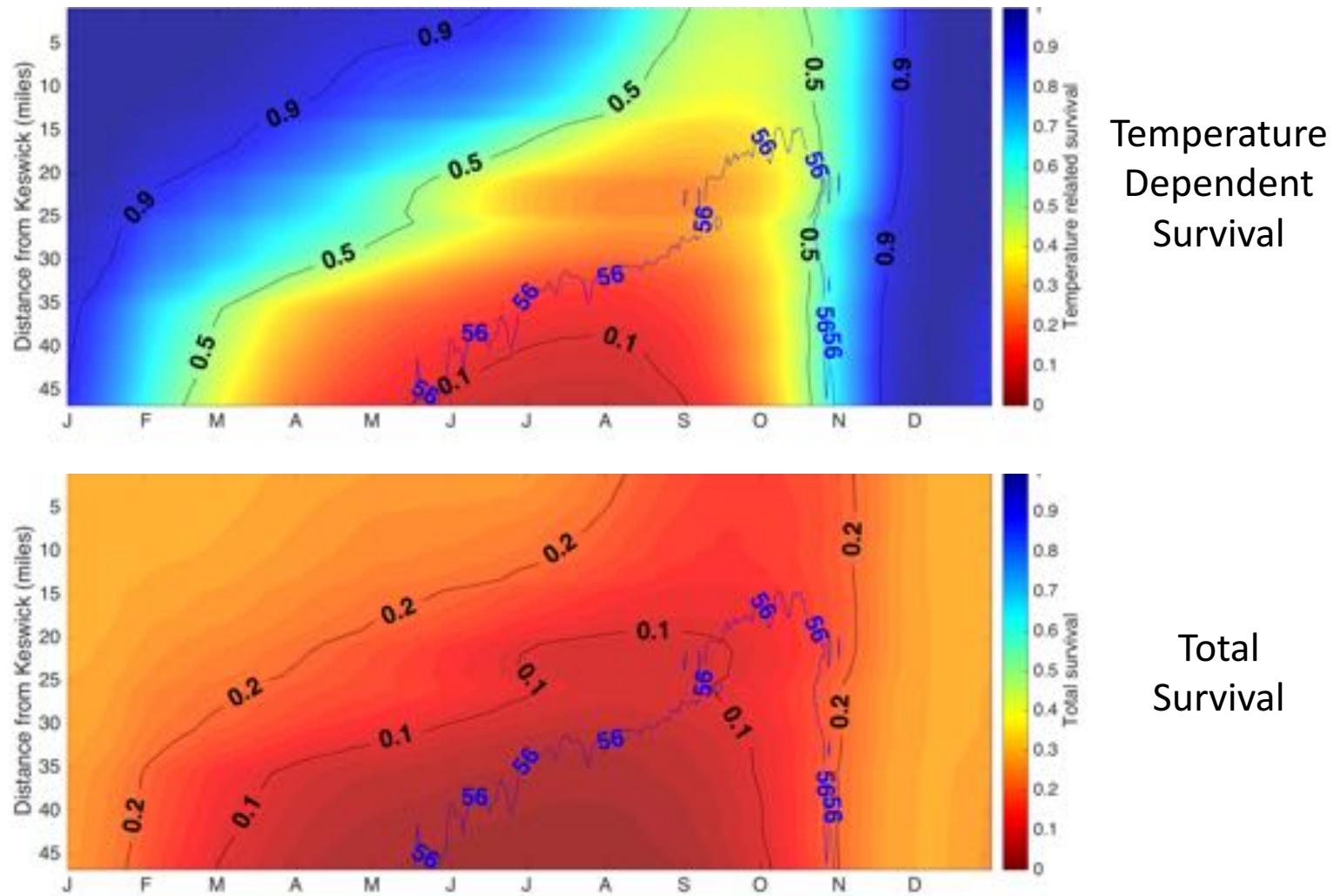
Temperature Landscape



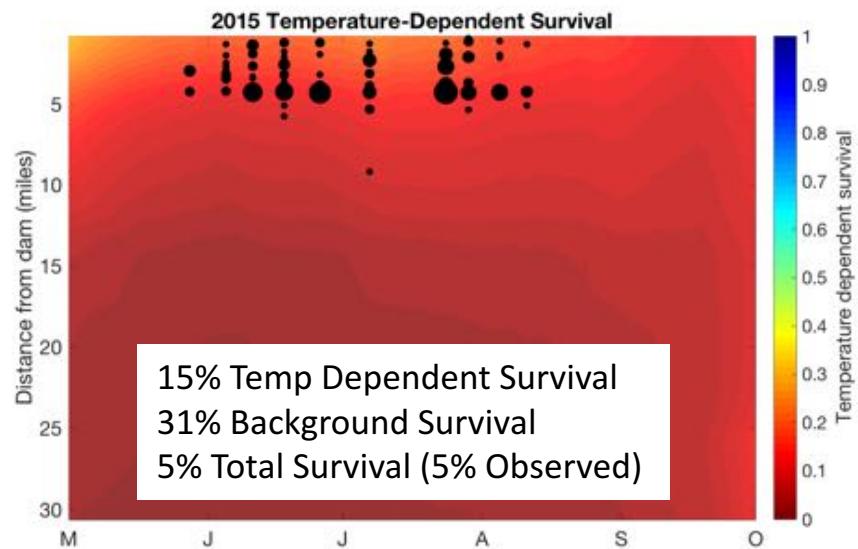
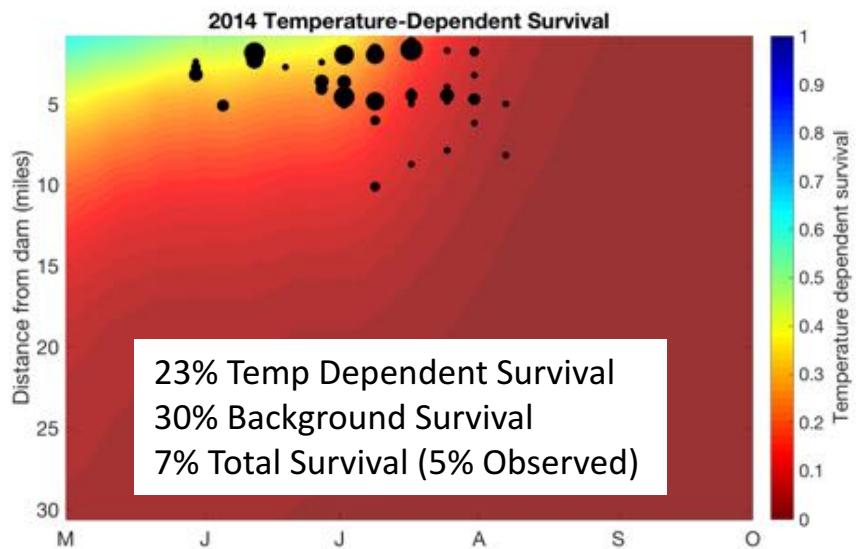
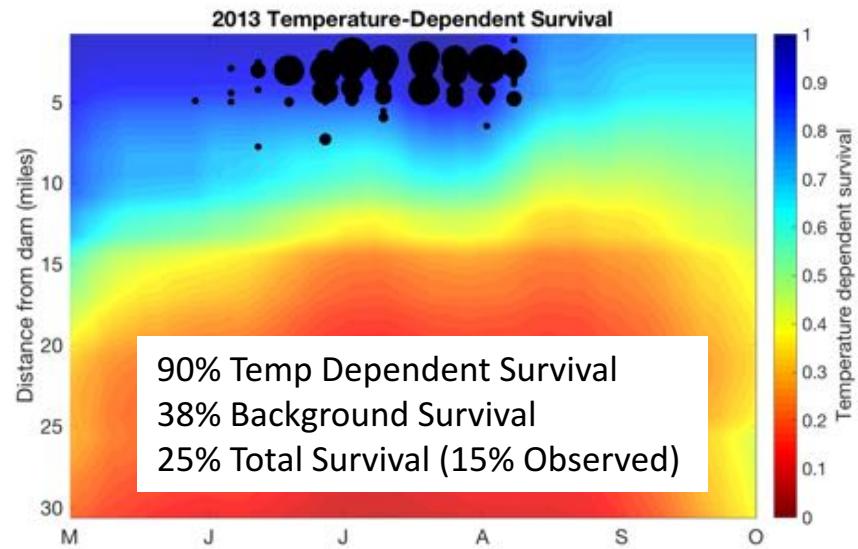
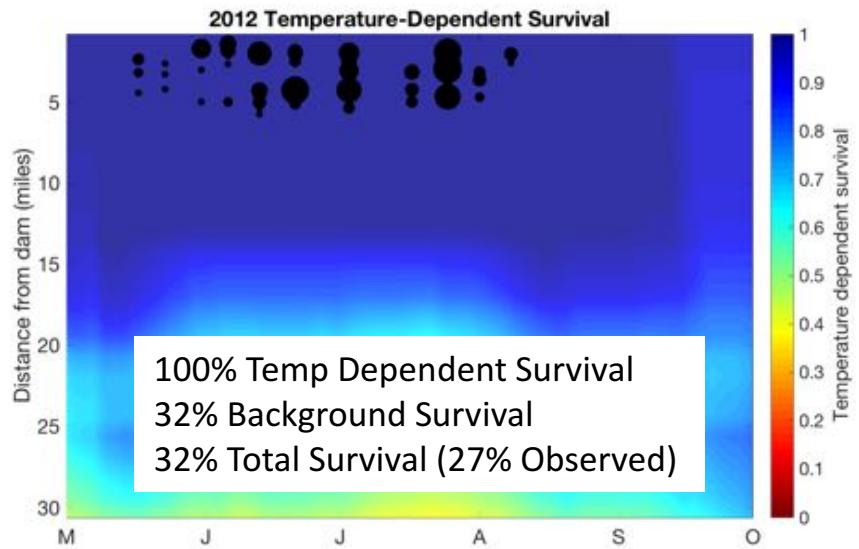
Egg survival as a function of temperature



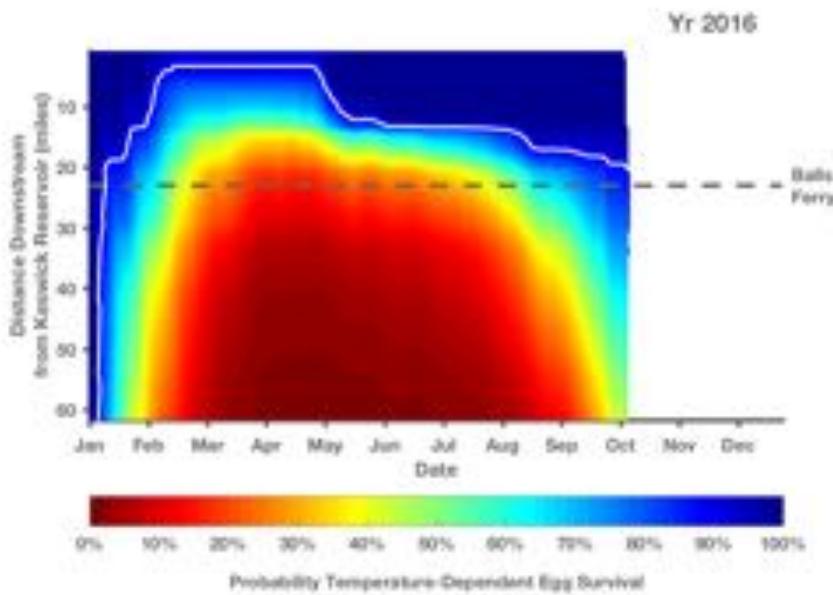
Total Survival =
Temperature Dependent Survival * Background Survival



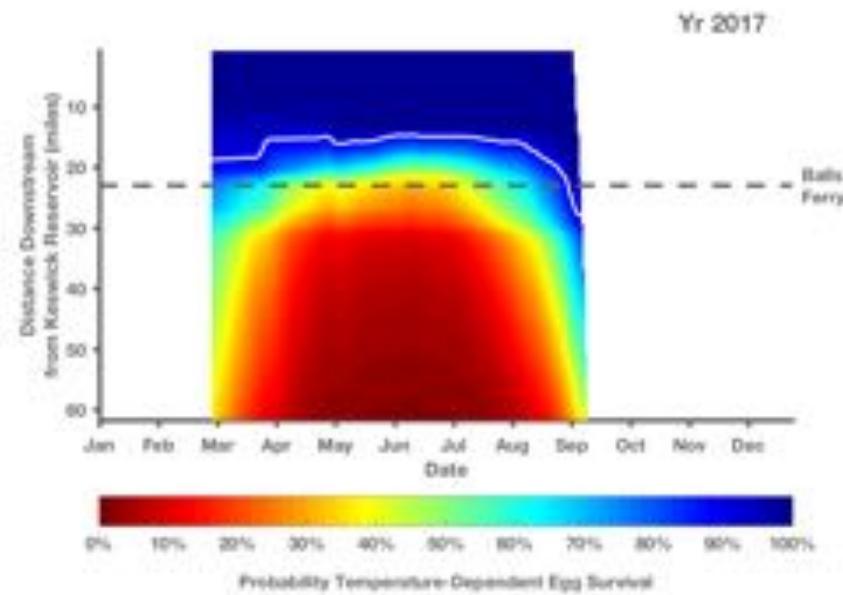
Heading into the drought...



The past two years

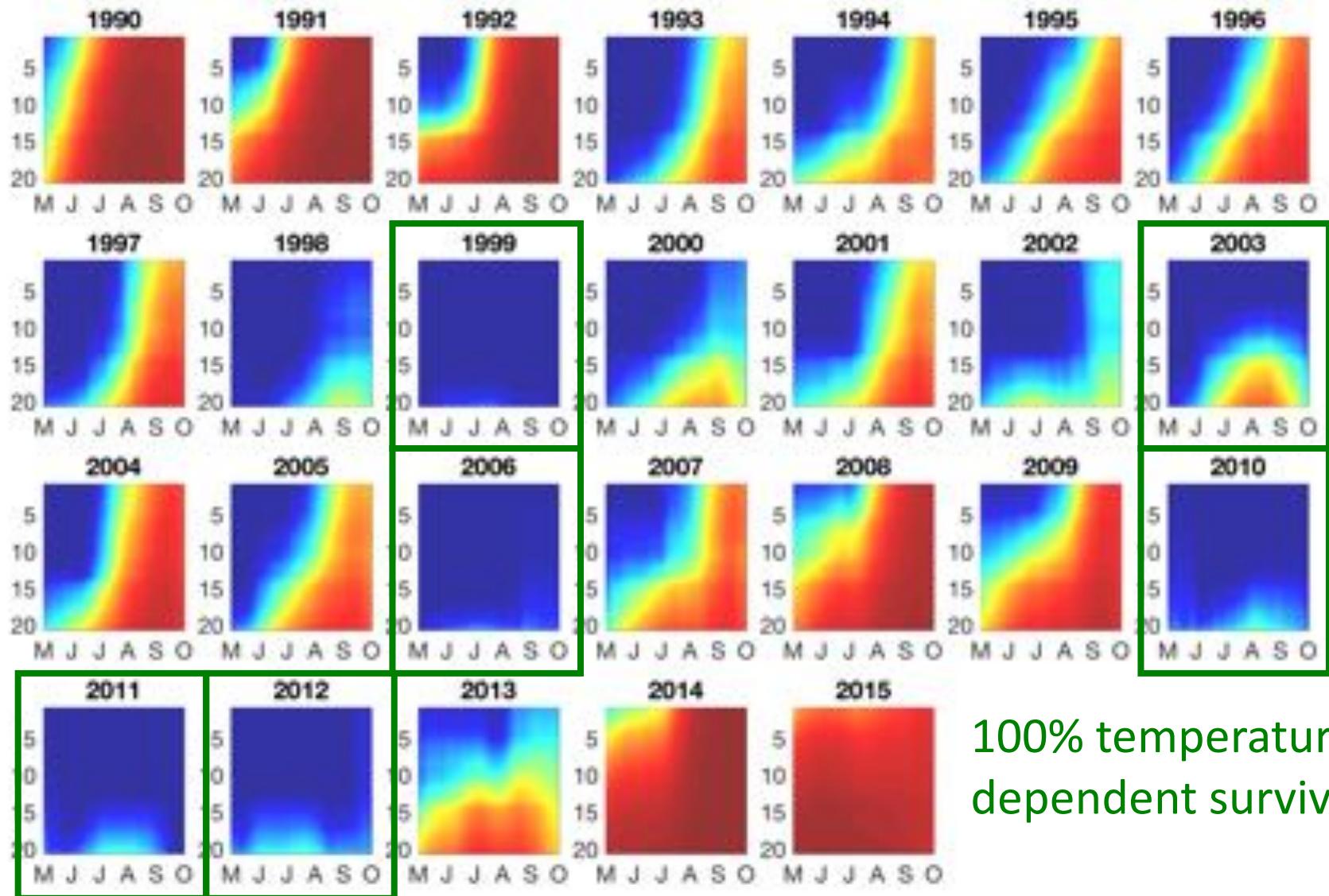


97.7% Temperature
Dependent Survival

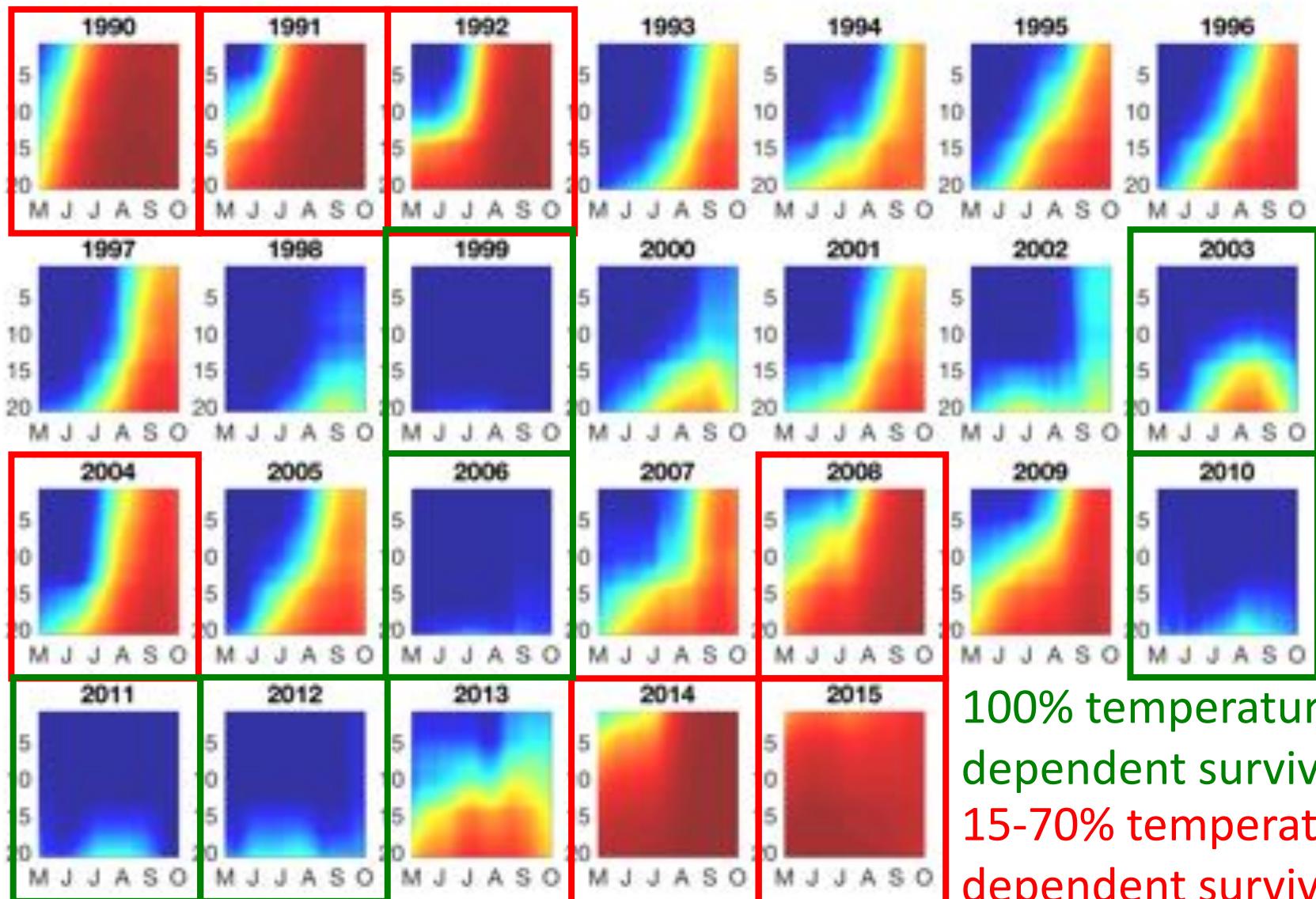


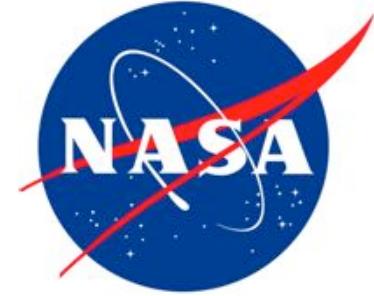
97.4% Temperature
Dependent Survival

Egg survival as a function of temperature



Egg survival as a function of temperature





Thank you

This work is supported by funding from
NASA Applied Sciences
US Bureau of Reclamation
and
NOAA Fisheries



JPL
Jet Propulsion Laboratory
California Institute of Technology

